This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Stanford University Libraries
3 6105 013 232 769

622.06
I59

Branner Earth Sciences Library

LIBRARY

TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

VOL. XI.—1895-96.

EDITED BY M. WALTON BROWN, SECRETARY.

NEWCASTLE-UPON-TYNE: PUBLISHED BY THE INSTITUTION.

PRINTED BY ANDREW REID & CO., LIMITED, NEWCASTLE-UPON-TYNE.
1896.

[*All rights of publication or translation are reserved.*]

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

1896.		PAGE.
Mar. 14.	—General Meeting (Leeds)	117
	"Adjustable Piston-rings." By H. Wormald	118
	Discussion	120
	Discussion on Prof. Lewes' paper on "Mining Explosives" ...	121
	Discussion on Mr. Alex. Reid's paper on "Methods of Closing the Tops of Upcast Winding Shafts"	122
	Discussion on Mr. A. W. Bennett's paper on "Telephonic Communications in and about Coal-mines"	124
	Discussion on Mr. Rankin Kennedy's paper on "Electrical Machinery for Mines"	125
April 18.	—General Meeting (Sheffield)	159
	Discussion on Mr. G. Blake Walker's paper on "The Roth Method of Firing Shots"	159
	Discussion on Mr. H. St. John Durnford's "Notes on the Sinking of the No. 1 Pit at the Ackton Hall Colliery," etc. ...	162
	Discussion on Prof. Lewes' paper on "Mining Explosives" ...	166
June 13.	—General Meeting (Wakefield)	227
	Proposed Alteration of Rules	227
	Discussion on Mr. Rankin Kennedy's paper on "Electrical Machinery for Mines"	228
	Discussion on Mr. T. Scott-Anderson's paper on "Electric Welding"	230
	Discussion on Mr. Robert Martin's paper on "The Treatment of Timber for Use in Mines"	231
	Discussion on Mr. H. St John Durnford's "Notes on the Sinking of the No. 1 Pit at the Ackton Hall Colliery," etc. ...	233
	Discussion on Mr. Hargrave Walters' paper on "Lead and Lap of Winding and other Engines'	233
July 22.	—Annual General Meeting (Barnsley)	485
	The Council's Annual Report	486
	Accounts...	488
	Election of Officers for 1896-97	490
	Representatives on the Council of The Federated Institution of Mining Engineers, 1896-97.	490
	Election of Officers by Ballot	491
	"Electric Coal-cutting on Longwall-faces." By T. B. A. Clarke	492
	Discussion	501
	"The Causes of Death in Colliery Explosions." By John S. Haldane	502
	Discussion	513

THE MINING INSTITUTE OF SCOTLAND.

1896.		
April 16.	—Annual General Meeting (Hamilton)	85
	Council's Report	85
	Accounts	87
	Election of Office-bearers	88
	Discussion on Mr. Robt. W. Dron's paper on "The Southern Ayrshire Coal-fields"	89

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

1896. PAGE.

Mar. 16.—General Meeting (Stoke-upon-Trent) 103
"The Use of Petroleum in Safety-lamps." By E. B. Wain ... 104
Discussion... 109
"The Woodworth Progressive Cut-off Gear for Winding-engines." By W. G. Cowlishaw 111
Discussion... 112
May 11.—General Meeting (Stoke-upon-Trent) 170
Technical Instruction 170
Discussion on Mr. T. H. Armstrong's paper on "The Rocket Oil-engine" 170
Discussion on Mr. J. J. Prest's paper on "Modern Coal-tipplers" 171
July 13.—General Meeting (Stoke-upon-Trent) 559
Discussion on Dr. J. S. Haldane's paper on "The Causes of Death in Colliery Explosions" 559
Discussion on Mr. C. E. de Rance's paper on "The Depth to Productive Coal-measures between the Warwickshire and Lancashire Coal-fields" 561

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

1896.

April 16.—General Meeting (Birmingham) 563
Technical Education 563
"Underground Haulage at Cannock and Rugeley Collieries." By Robert S. Williamson 564
June 18.—General Meeting (Birmingham) 572
Representatives on the Council of The Federated Institution of Mining Engineers 572
Technical Education 572

APPENDICES.

I.—Notes of Papers on the Working of Mines, Metallurgy, etc., from the Transactions of Colonial and Foreign Societies and Colonial and Foreign Publications 573
"Acetylene Lamp." *Anon.* 573
"The Crédo Deposit of Asphalt and Petroleum, France." By — Boulangier 573
"Dust-firing in Brown-coal Briquette Works." By Dr. Kossman 574
"Propfe Mill for Coal-dust Fuel." By S. E. 574
"Coal-dust Furnaces." By F. Bleichsteiner 575
"Powdered Coal-firing." By Victor V. Neumann 576
"The Combustion of Coal in Air." By Alex. Naumann ... 580
"The Smoke Question." By Messrs. Von Schröder and W. Schmitz-Dumont... 580

APPENDICES.—*Continued.* PAGE.

1 —Notes of Papers on the Working of Mines, Metallurgy, etc —*Continued.*
"Expansion-dampers for the Furnaces of Boilers with Small Water-Tubes." By C. Walckenaer 581
"The Dubiau Water-circulating Apparatus." *Anon.* 582
"Raky System of Boring." *Anon.* 582
"Determining the Calorific Value of Fuel." By E. Goutal ... 583
"Calorimeter for Determining the Heating Value of Coals." By R. C. Carpenter 584
"Outbursts of Carbonic Acid Gas":—
(1) By El. 584
(2) *Anon.* 585
"The Transport Theory of Coal Formation." By the Rev. G. Schmitz 585
"The Fusibility and Composition of Coal-ash." By Eugène Prost 586
"Anthracite in the Permian Rocks of Bohemia, Austria." By Dr. Fr. Katzer 587
"The Southern Portion of the Valenciennes Coal-field, France." By — Chapuy 589
"Geology of the Bayer Shaft and Adjacent Portion of the Pilsen Coal-basin, Bohemia." By K. A. Weithofer 590
"The Donetz Coal-field, Russia":—
(1) By Petau de Maulette 593
(2) By Paul Trasenster 593
(3) By Gustav Krenke 594
"Villanueva Coal-field, Spain." *Anon.* 596
"Puertollaño Coal-field, Spain." By Manuel Sanchez y Massia 596
"Coal in the Transvaal." By M. Lapierre 597
"Ancient Copper Mines of Sinai." By Prof. Berthelot ... 598
"Needle Weirs." *Anon.* 599
"Electric Power-transmission in Mines":—
(1) By C. Köttgen 599
(2) *Anon.* 600
(3) *Anon.* 600
(4) By — Baily 601
"Gas and Petroleum Motors." By C. Lambotte 602
"Advantages of Compressed Air." By — Mortier 602
"The Laval Steam-turbine." By A. Stévart 603
"Expansion in Winding-engines." By — Berne 604
"Explosion at the Hohenegger Shaft, Karwin." By Josef Böhm 605
"Detonators for Explosives." By M. Rückgaber 607
"Dangers of Blasting in Fiery Mines." By Franz Brzezowski 608
"Percussion-detonators." By Joseph Popper 609
"Delayed Ignition of Grisounite Cartridges." By — Sarrau... 610
"Composition of Fire-damp." By M. Schloesing, Jun. ... 611
"Combustible Gas in a Non-fiery Mine." By — Leproux ... 612
"Disengagements of Inflammable Gas from Mines of Plastic Clay":—
(1) By — Oppermann 613
(2) By — Humbert 614

APPENDICES.—*Continued.*

I.—Notes of Papers on the Working of Mines, Metallurgy, etc.—*Continued.*

"Testing Return Air-currents in the Saar Coal-field, Germany." *Anon.* 615
"Coquillion Fire-damp Indicator." By J. Coquillion... ... 616
"Hardy Fire-damp Indicator." By — Termier 617
"Fire at the Kleophas Colliery, Upper Silesia." *Anon.* ... 618
"Interception of Dust and Metallic Fumes." By U. Le Verrier 619
"Continuous and Automatic Apparatus for taking Samples of Air or Gas." By — Petit 619
"Composition of Mine-atmospheres in the Donetz Coal-field, Russia." By N. Kotsovsky 620
"Origin of Subterranean Cavities and their Connexion with Mineral Veins." By E. A. Martel 621
"Gold Extraction: the Cassel-Hinman Bromine Process." By P. C. McIlhiney 622
"Gold Extraction by Potassium Cyanide." By J. Loewy ... 623
"Gold Mines of the Duerno, Spain." By R. Oriol 623
"The Present Method of Declaring the Monthly Output of Gold of the Witwatersrand District, with a Suggestion for its Alteration." By A. Von Gernet 624
"Gold Metallurgy on the Witwatersrand, S.A.R." By W. R. Feldtmann 625
"Auriferous Gravels of the Upper Columbia River, British Columbia." By Frank L. Nason 626
"Camp Floyd Mining District, Utah, U.S.A." By James W. Neill 627
"Gold Mining in Western Australia." By Dr. C. Schmeisser 628
"The Refractory Gold-ores of Queensland: their Sources and Treatment." By E. A. Weinberg 631
"Haulage-installation at the Fuchs Colliery, Lower Silesia." By Fr. Stolz 631
"Endless-rope Haulage at the Roland Colliery, Rhenish Prussia." By W. Bentrop 633
"Axle-box for Mine Tubs." By — Gardon 633
"Brake and Pulley for Self-acting Inclines." By Prosper Vanhassel... 634
"Balance with Water-brake for Lowering Gob Material." By — Baudrey 634
"Roasting Iron and Manganese Ores." By S. Jordan ... 635
"A Mine Owned and Worked by Miners in France." By — Villot 636
"Responsibility for Damage caused by Industrial Establishments in France." By Léon Michel... 637
"Efficiency of a Locomotive Engine with Separate Steam and Exhaust-valves." By Ernest Polonceau 637
"Methods of Testing Materials." *Anon.* 638
"Occurrence of Mercury in the Asturias, Spain." By A. Dory 639
"Self-acting Waggon-tippler." *Anon.* 640

APPENDICES.—*Continued.*

PAGE.

I.—Notes of Papers on the Working of Mines, Metallurgy, etc.—*Continued.*

"Ore-concentrators":—

(1) By L. Kirschner 640

(2) By Julius Schwartz... 642

"Oberegger Coal-screen." By V. Waltl... 644

"Experiments with Frue Vanners." By S. Rákóczy 645

"Francou Method of Coal-washing." *Anon.* 647

"Spectrum Analysis of Minerals." By Victor Deshayes ... 648

"Ore-deposits of San Luis, Argentine Republic." By Dr. J. Valentin 649

II.—"Barometer, Thermometer, etc., Readings for the Year 1895." By M. Walton Brown 651

INDEX 661

LIST OF PLATES:—

	PAGE.		PAGE
I., II., III., IV., V., VI. ...	6	XVII.	304
VII.	36	XVIII.	332
VIII.	58	XIX.	344
IX.	102	XX., XXI.	376
X....	120	XXII., XXIII., XXIV., XXV.	458
XI.	134	XXVI., XXVII.	470
XII.	166	XXVIII....	482
XIII.	204	XXIX.	550
XIV.	212	XXX., XXXI....	570
XV.	226	XXXII., XXXIII.	660
XVI.	290		

"REPORT OF THE PROCEEDINGS OF THE FLAMELESS EXPLOSIVES COMMITTEE." BY A. C. KAYLL, ENGINEER. Pages i.-vii. and 1-136; with Frontispiece and Plates I.-IV.

ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, *i.e.*, "ANNUAL REPORT," "LIST OF MEMBERS," ETC., ETC.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

BYE-LAWS

Passed at Council Meeting held on May 28th, 1891.

I.—CONSTITUTION.

1.—The Federated Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering, and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

(*a*) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.

(*b*) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.

(*c*) The publication of original communications, discussions, and other papers connected with the objects of the Institution.

(*d*) The purchase and disposal of real and personal property for such objects.

(*e*) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

II.—MEMBERSHIP.

6.—The original adherents or founders are as follows :—

(*a*) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.

(*b*) Midland Institute of Mining, Civil, and Mechanical Engineers, Barnsley.

(*c*) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

(*d*) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—"The members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students :—

(*a*) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.

(*b*) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.

(*c*) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.

(*d*) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

(*e*) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members, and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

III.—Subscriptions.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate, and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Federated Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

IV.—Election of Officers and Council.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one

Vice-President per two hundred Ordinary Members or Associate Members thereof; and of a President elected by and from the Council at their first meeting in each year; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

V.—Duties of Officers and Council.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer, and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

VI.—General Meetings.

38.—An ordinary general meeting shall be held in February, May, and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

VII.—PUBLICATIONS.

41.—The publications may comprise:—

(*a*) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.

(*b*) Papers on the management of industrial operations.

(*c*) Abstracts of foreign papers upon similar subjects.

(*d*) An abstract of the patents relating to mining and metallurgy, etc.

(*e*) Notes of questions of law concerning mines, manufactures, railways, etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes, shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of the Federated Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Federated Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council; to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution as a body is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution, or of the Federated Institutes.

VIII.—Medals and other Rewards.

55.—The Council may award annually the sum of twenty pounds, in the form of medals or other rewards, to the authors of papers published by the Institution.

IX.—Property.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses :—

(*a*) The interest of its accumulated capital fund;

(*b*) The annual subscriptions ; and

(*c*) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books, and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

X.—Alteration of Bye-Laws.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting, and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

OFFICERS, 1895-96.

President.

Mr. GEORGE A. MITCHELL, 5, West Regent Street, Glasgow.

Vice-Presidents.

Mr. W. N. ATKINSON, Newcastle, Staffordshire (Past-President).
Mr. EMERSON BAINBRIDGE, Nunnery Colliery Offices, Sheffield.
Mr. W. COCHRANE, St. John's Chambers, Grainger Street West, Newcastle upon-Tyne.
Mr. JOHN DAGLISH, Rothley Lake, Cambo, R.S.O., Northumberland.
Mr. T. DOUGLAS, The Garth, Darlington.
Mr. JAMES T. FORGIE, Bothwell Collieries, Bothwell, Glasgow.
Mr. W. E. GARFORTH, West Riding Colliery, Normanton.
Mr. GEORGE LEWIS, Albert Street, Derby (Past-President).
Mr. GEORGE MAY, The Harton Collieries, South Shields.
Mr. JOHN NEVIN, Littlemoor House, Mirfield.
Mr. H. C. PEAKE, Walsall Wood Colliery, Walsall.
Mr. FRED. J. ROWAN, 121, West Regent Street, Glasgow.
Mr. ARTHUR SOPWITH, Cannock Chase Collieries, near Walsall (Past-President).
Mr. WILLIAM SPENCER, Southfields, Leicester.
Mr. A. L. STEAVENSON, Durham.
Mr. EDWARD B. WAIN, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.

Council.

* Deceased.

Mr. W. ARMSTRONG, Jun., Wingate, Co. Durham.
Mr. JAMES BARROWMAN, Stanecare, Hamilton, N.B.
Mr. T. W. BENSON, 11, Newgate Street, Newcastle-upon-Tyne.
Mr. G. J. BINNS, Netherseal Colliery, Burton-upon-Trent.
Mr. W. C. BLACKETT, Acorn Close, Sacriston, Durham.
Mr. M. WALTON BROWN, 5, Lambton Road, Newcastle-upon-Tyne.
Mr. T. FORSTER BROWN, Guildhall Chambers, Cardiff.
Mr. H. M. CADELL, Grange, Bo'ness, R.S.O., Linlithgowshire.
Mr. A. M. CHAMBERS, Thorncliffe Collieries, near Sheffield.
Mr. W. F. CLARK, The Poplars, Aldridge, near Walsall.
Mr. G. E. COKE, 65, Station Street, Nottingham.
Mr. ROBERT HEATH COLE, Endon, Stoke-upon-Trent.
Mr. MAURICE DEACON, Blackwell Collieries, Alfreton.
Mr. JAMES S. DIXON, Fairleigh, Bothwell, Glasgow.
Mr. T. E. FORSTER, 3, Eldon Square, Newcastle-upon-Tyne.

Mr. ALEX. M. GRANT.
Mr. J. R. HAINES, Adderley Green Collieries, Stoke-upon-Trent.
Mr. JAMES HASTIE, Greenfield Colliery, Hamilton, N.B.
Mr. W. J. HAYWARD, West Bromwich.
Mr. JEREMIAH HEAD, 47, Victoria Street, Westminster, London, S.W.
Mr. WILLIAM HEATH, Sneyd House, Burslem, Stoke-upon-Trent.
Mr. J. L. HEDLEY, 2, Devonshire Terrace, Newcastle-upon-Tyne.
Mr. W. F. HOWARD, 15, Cavendish Street, Chesterfield.
Mr. JOHN JACKSON, Stubben Edge, Chesterfield.
Mr. A. C. KAYLL, Gosforth, Newcastle-upon-Tyne.
Mr. C. C. LEACH, Seghill Colliery, Northumberland.
Mr. HENRY LEWIS, Annesley Colliery, Nottingham.
Mr. J. LONGBOTHAM, Barrow Collieries, Barnsley.
Mr. J. A. LONGDEN, Stanton-by-Dale, Nottingham.
Mr. J. H. MERIVALE, Togston Hall, Acklington, Northumberland.
Mr. M. H. MILLS, Mansfield Woodhouse, Mansfield.
Mr. T. W. H. MITCHELL, Eldon Street, Barnsley.
*Mr. RALPH MOORE, 13, Clairmont Gardens, Glasgow.
Mr. JOHN MORISON, Cramlington House, Northumberland.
Mr. HENRY PALMER, Medomsley, R.S.O., Co. Durham.
Mr. M. W. PARRINGTON, Wearmouth Colliery, Sunderland.
Mr. A. M. POTTER, Aydon Grange, Corbridge-upon-Tyne.
Mr. T. O. ROBSON, Chowdene Cottage, Low Fell, Gateshead-upon-Tyne.
Mr. FRED SILVESTER, Newcastle, Staffordshire.
Mr. ALEXANDER SMITH, 3, Newhall Street, Birmingham.
Mr. JOHN STRICK, Bar Hill, Madeley, Staffordshire.
Mr. SIMON TATE, Trimdon Grange Colliery, Co. Durham.
Mr. WALLACE THORNEYCROFT, Merryton Colliery, Hamilton, N.B.
Mr. G. BLAKE WALKER, Wharncliffe Silkstone Colliery, Barnsley.
Mr. FRANK N. WARDELL, Wath-upon-Dearne, near Rotherham.
Mr. JAMES WALLACE, Wester Gartshore Colliery, Kirkintilloch, Glasgow.
Mr. J. G. WEEKS, Bedlington, R.S.O., Northumberland.
Mr. R. L. WEEKS, Willington, Co. Durham.

Auditor.

Mr. JOHN G. BENSON, Newcastle-upon-Tyne.

Treasurer.

Mr. REGINALD GUTHRIE, Neville Hall, Newcastle-upon-Tyne.

Secretary.

Mr. M. WALTON BROWN, Neville Hall, Newcastle-upon-Tyne.

LIST OF MEMBERS.

Honorary Members.

* Deceased.

The Federated Institution of Mining Engineers.

J. B. ATKINSON, H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
W. N. ATKINSON, H.M. Inspector of Mines, Newcastle, Staffordshire.
W. BEATTIE-SCOTT, H.M. Inspector of Mines, Great Barr, near Birmingham.
THOMAS BELL, 15, Valley Road, Scarborough.
C. LE NEVE FOSTER, H.M. Inspector of Mines, Llandudno.
JOHN GERRARD, H.M. Inspector of Mines, Worsley, near Manchester.
HENRY HALL, H.M. Inspector of Mines, Rainhill, Lancashire.
J. L. HEDLEY, H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
J. S. MARTIN, H.M. Inspector of Mines, The Vikings, 16, Durdham Park, Bristol.
JOSEPH T. ROBSON, H.M. Inspector of Mines, Swansea.
J. M. RONALDSON, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
A. H. STOKES, H.M. Inspector of Mines, Greenhill, Derby.
FRANK N. WARDELL, H.M. Inspector of Mines, Wath-upon-Dearne, near Rotherham.

Chesterfield and Midland Counties Institution of Engineers.

PROF. FRANK CLOWES, University College, Nottingham.
REV. J. M. MELLO, Mapperley Vicarage, near Derby.

Midland Institute of Mining, Civil, and Mechanical Engineers.

PROF. G. F. ARMSTRONG, The University, Edinburgh.
JOSEPH DICKINSON, South Bank, Sandy Lane, Pendleton, Manchester.
PROF. GOODMAN, Yorkshire College, Leeds.
*PROF. A. H. GREEN, 137, Woodstock Road, Oxford.
PROF. L. C. MIALL, Yorkshire College, Leeds.
PROF. ERRINGTON RUCKER, Science and Art Department, South Kensington, London, S.W.
PROF. R. RUSSELL, 1, Sea View, St. Bees, Carnforth.
PROF. T. E. THORPE, The Government Laboratory, Somerset House, London, W.C.

The Mining Institute of Scotland.

*RALPH MOORE, 13, Clairmont Gardens, Glasgow.

North of England Institute of Mining and Mechanical Engineers.

The Right Honourable the EARL OF RAVENSWORTH, Ravensworth Castle, Gateshead-upon-Tyne.
PROF. P. PHILLIPS BEDSON, Durham College of Science, Newcastle-upon-Tyne.
PROF. G. S. BRADY, Durham College of Science, Newcastle-upon-Tyne.
DR. BRASSERT, Bonn-am-Rhein, Germany.
JOS. DICKINSON, South Bank, Sandy Lane, Pendleton, Manchester.
PROF. WILLIAM GARNETT, 13, Spring Gardens, London, S.W.

Rev. H. P. Gurney, Principal of the Durham College of Science, Roseworth, Gosforth, Newcastle-upon-Tyne.
Prof. A. S. Herschel, Observatory House, Slough, Bucks.
Prof. G. A. Lebour, Durham College of Science, Newcastle-upon-Tyne.
*J. A. Longridge, Grêve d'Ayetté, Jersey.
John H. Merivale, Togston Hall, Acklington, Northumberland. *Transactions* to be sent to the Secretary, Durham College of Science, Newcastle-upon-Tyne.
Prof. H. Stroud, Durham College of Science, Newcastle-upon-Tyne.
E. Vuillemin, Mines d'Aniche, Nord, France.

North Staffordshire Institute of Mining and Mechanical Engineers.

W. N. Atkinson, H.M. Inspector of Mines, Newcastle, Staffordshire.
Hugh R. Makepeace, H.M. Inspector of Mines, Newcastle, Staffordshire.
R. P. W. Oswald, H.M. Inspector of Mines, 28, Lismore Terrace, Carlisle.
Henry Skiffington Poole, Acadia Coal Company, Ltd., Stellarton, Nova Scotia.
A. R. Sawyer, P.O. Box 2233, Johannesburg, Transvaal, and 40, Brompton Square, London, S.W.
C. M. Stuart, St. Dunstan's College, Lewisham.

South Staffordshire and East Worcestershire Institute of Mining Engineers.

Prof. C. Lapworth, Mason College, Birmingham.
Prof. R. H. Smith, Mason College, Birmingham.

Members.

* Deceased.

Abraham, David, Pencoedcae, Merthyr Tydvil.
Aburrow, Charles, P.O. Box 534, Johannesburg, Transvaal.
Ackroyd, A., Morley Main Collieries, Leeds.
Ackroyd, Wm., Morley Main Collieries, Morley, near Leeds.
Adams, David, Muircambus, Colinsburgh, R.S.O., Fifeshire.
Adamson, J. C., Victoria Place, Airdrie, N.B.
Adamson, T., Kurhurbaree Colliery, E.I.R., Bengal, India.
Addie, Alexander, 67, Johnstone Street, Airdrie, N.B.
Agabeg, Frank J., Apcar and Co.'s Collieries, Sitarampore, India.
Agassiz, Alexander, Museum of Comparative Zoology, Cambridge, Mass., U.S.A.
Ainsworth, J. W., Bridgewater Trustees Collieries, Walkden, near Bolton, Lancashire.
Aitken, Henry, Darroch, near Falkirk, N.B.
Alison, Robert, Leafield, Burnbank Road, Hamilton, N.B.
Allan, Alexander B., 7, Campside Crescent, Langside, Glasgow.
Allan, C. J. G., Electric House, West Calder, N.B.
Allan, George, Corngreaves Hall, Birmingham.
Allan, James, Hillhead, Coylton, Ayr, N.B.
Allan, John, South Cobbinshaw, Carstairs, Lanark, N.B.
Allan, John F., Apartado de Correo No. 121, Mexico, D.F.
Allan, T. A., c/o Messrs. Gibbs, Bright, and Co., Melbourne, Australia.
Allardice, James, Lancethill Cottage, Lesmahagow, N.B.

ALLCHURCH, ENRIQUE, Calle Las Heras, 289, Buenos Aires, Argentine Republic.
ALLEN, REUBEN, Birch Coppice Colliery, Polesworth, near Tamworth.
ALLISON, JOHN, 59, Waterloo Street, Glasgow.
ALLISON, J. J. C., Woodland Collieries, Butterknowle, R.S.O., Co. Durham.
ALLSOP, SAMUEL, Marehay Collieries, Derby.
ALSOP, A. B., Pinxton Collieries, Alfreton.
ALSOP, A. M., Lead Mines, Darley Dale, Matlock.
ALSOP, SAMUEL, Morley Park Iron Works, Codnor, Derby.
ALSTON, CHARLES F., Pilgrims Rest, South African Republic.
ANDERSON, CARL, Mogollon, New Mexico, U.S.A.
ANDERSON, C. W., Cleadon Park, Sunderland.
ANDERSON, GEORGE, 237, Collins Street, Melbourne, Australia.
ANDERSON, JAMES, Farme Colliery, Rutherglen, Glasgow.
ANDERSON, JOHN, Ellenslee, Wilson Street, Motherwell, N.B.
ANDERSON, R. HAY, 13, San Juan de Letran, Mexico, D.F.
ANDERSON, R. S., Elswick Colliery, Newcastle-upon-Tyne.
ANDERSON, WALTER G., Anglo-American Club, Freiberg, Saxony, Germany.
ANDREW, ROBERT, c/o John Munro, 30, George Square, Glasgow.
ANDREWS, THOMAS, Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent.
ANDREWS, THOMAS, Wortley Iron Works, near Sheffield.
ANGOVE, WM. HENRY, Albany, Western Australia.
ANGUS, JAMES, Radcliffe, Acklington, Northumberland.
ANGWIN, B., P.O. Box 231, Johannesburg, Transvaal.
ANLEY, JAMES P. B., The Avenue, Kidsgrove, Stoke-upon-Trent.
APPLEBY, W. R., 911, Fifth Street, S.E., Minneapolis, Minn., U.S.A.
ARCHER, JOSEPH, Royal Insurance Buildings, Church Street, Sheffield.
ARCHER, T., 6, Park Terrace, Gateshead-upon-Tyne.
ARCHER, WILLIAM, Victoria Garesfield, Lintz Green.
ARCHIBALD, DAVID, Niddrie Collieries, Portobello, N.B.
ARGALL, CAPT. J., Nant-y-Mwyn Mines, Llandovery, Wales.
ARGALL, PHILIP, P.O. Box 1095, Denver, Colorado, U.S.A.
ARMOUR, JAMES, Clippens Oil Works, Loanhead, N.B.
ARMSON, JESSE, Coleorton Colliery, Ashby-de-la-Zouch.
ARMSTRONG, HY., Chester-le-Street.
ARMSTRONG, LORD, C.B., LL.D., D.C.L., Cragside, Rothbury.
ARMSTRONG, THOS. HENRY, Blanchland House, Newcastle-upon-Tyne.
*ARMSTRONG, WM., Pelaw House, Chester-le-Street.
ARMSTRONG, WM., Jun., Wingate, Co. Durham.
ARMSTRONG, W. J.
ARNOLD, T., Castle Hill, Greenfields, Llanelly.
ARNOTT, THOMAS, Fernbank, Newton, Glasgow.
ASHCROFT, EDGAR A., Willyama Works, Globe Works, Grays, Essex.
ASHCROFT, HARRY, Borrea Coal Co., Limited, Seetarampore, Bengal, India.
ASHTON, J. H., Waleswood Colliery, near Rotherham.
ASHWIN, G. H., Charity Colliery, Bedworth, near Nuneaton.
ASHWORTH, THOMAS, 25, Regent Road, Fenton, Stoke-upon-Trent.
ASKEW, GEORGE H., Brayton Domain Collieries, Aspatria, Cumberland.
ASQUITH, T. W., Harperley Hall, Tantobie, R.S.O., Co. Durham.
ASTON, J., Blowers Green, Dudley, Worcestershire.
ATKINS, S. S., Coalbrooke Farm, Woodhouse Mill, Rotherham.
ATKINSON, A. A., Barrow Collieries, Barnsley, Yorkshire.

ATKINSON, C. W., S. Z. de Ferranti, Limited, Hollinwood.
ATKINSON, FRED. R., West Street, Congleton.
ATKINSON, J. B., H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
ATKINSON, J. W., Sterndale Road, Millhouses, Sheffield.
ATKINSON, L. B., 10, Westbourne Road, Penarth, South Wales.
ATKINSON, T. D., Hearn House, Chesterfield.
ATKINSON, W. N., H.M. Inspector of Mines, Newcastle, Staffordshire.
ATTERBURY, BASIL J., 141, Copthall House, Copthall Avenue, London, E.C.
AUBREY, R. C., 61, Bath Street, Southport.
AUSTIN, W. LAWRENCE, P.O. Box 941, Denver, Colorado, U.S.A.
AYTON, ERNEST F., El Bote Mining Negociacion, Zacatecas, Republic of Mexico.
AYTON, HENRY, 122, Rye Hill, Newcastle-upon-Tyne.

BAILES, E. T., Wingate, Ferryhill.
BAILES, G. M., Coton Road, Nuneaton.
BAILES, T., Jesmond Gardens, Newcastle-upon-Tyne.
BAILEY, E. J., 30, Waterloo Street, Birmingham.
BAILEY, SAMUEL, 30, Waterloo Street, Birmingham.
BAILEY, S. & J., 30, Waterloo Street, Birmingham.
BAIN, JAMES, Brae Cottage, Motherwell, N.B.
BAIN, R. DONALD, H.M. Inspector of Mines, 85, Pembroke Road, Clifton, Bristol.
BAINBRIDGE, EMERSON, Nunnery Colliery Offices, Sheffield.
BAIRD, ARCHIBALD, Park Road, Hamilton, N.B.
BAIRD, DUGALD, Radcliffe Colliery, Acklington, Northumberland.
BAIRD, JAMES, Inkermann Works, Paisley, N.B.
BAIRD, MATTHEW B., Hillside, Hamilton, N.B.
BAIRD, ROBERT, 46, Gordon Street, Glasgow.
BALFOUR, J. L., Hannans Star Gold Mining Company, Kalgoorlie, Western Australia.
BALLINGAL, NEIL, Sweet Bank, Markinch, N.B.
BANCROFT, ROBERT E., 8, St. James' Square, Manchester.
BANHAM, E. G., Barrow Collieries, Barnsley.
BANKS, THOMAS, 29, The Park, Eccles, near Manchester.
BANNISTER, DAVID, Shawcross, near Dewsbury.
BARKER, M. W., P.O. Box 1463, Johannesburg, Transvaal.
BARLOW, J. W., Hardwick Colliery, Heath, Chesterfield.
BARNARD, A. H., The Green, Pelsall, Walsall.
BARNES, ALFRED, Ashgate Lodge, Chesterfield.
BARNES, A. G., Tupton Hall, Claycross, Chesterfield.
BARNES, A. T. H., Grassmoor Collieries, Chesterfield.
BARR, WILLIAM, Machanhill House, Larkhall, R.S.O., Lanarkshire.
BARRACLOUGH, SAMUEL, Union Foundry, Barnsley.
BARRETT, C. R., Whitehill Hall, Chester-le-Street.
BARRON, THOS., Rylands Main Colliery, Barnsley.
BARROWMAN, JAMES, Stancacre, Hamilton, N.B.
BARTHOLOMEW, C. W., Blakesley Hall, Towcester.
BARWELL, W. H., Fence Cottage, Woodhouse Mill, Rotherham.
BATEMAN, JAMES T., Fair View, Bebington, near Birkenhead.
BATES, SIDNEY, Mickley Colliery Offices, Stocksfield-upon-Tyne.
BATES, THOMAS., The Grange, Prudhoe-upon-Tyne.
BATES, W. R., Pye Bridge House, near Alfreton.

BATEY, JOHN, Newbury Collieries, Coleford, Bath.
BATTY, W., Darley Grove, Worsbro' Dale, Barnsley.
BAUMGARTNER, W. O., Whitburn, near Sunderland.
BAYLDON, DANIEL HY., c/o New Zealand Mines Trust, Limited, Auckland, New Zealand.
BAYLEY, THOMAS, Peverel House, Nottingham.
BEACHER, A. L., Lundhill Colliery, Barnsley.
BEANLANDS, ARTHUR, Palace Green, Durham.
BEARD, A., Carlton Villa, Carlton, near Barnsley.
BEATON, HENRY, Balbardie Colliery, Bathgate, N.B.
BEDDOE, E. C., Bank Chambers, Dudley, Worcestershire.
BEECH, NOEL TENCH, Lilleshall Collieries, St. George's, Wellington, Salop.
BEITH, ROBERT, Cwmhowell House, Llannon, Llanelly, South Wales.
BELFITT, WM., Bretby Colliery, Burton-upon-Trent.
BELL, ALAN D., Chandler Iron Works, Ely, Minn., U.S.A.
BELL, GEORGE FRED, H.M. Inspector of Mines, 30, Eldon Street, Newcastle-upon-Tyne.
BELL, JAMES, The Lührig Appliances, Limited, 32, Victoria Street, London, S.W.
BELL, Sir LOWTHIAN, Bart., D.C.L., Rounton Grange, Northallerton.
BELL, R. G., 42, Burdon Terrace, Newcastle-upon-Tyne.
BELL, WALTER, 23, Windsor Terrace, Newcastle-upon-Tyne.
BELLINGHAM, GEO., Bayley Street, Coolgardie, Western Australia.
BENNETT, ALFRED H., Dean Lane Collieries, Bedminster, Bristol.
BENNETT, A. W., 34, Fenton Street, Leeds.
BENNETT, J., Langwith Colliery, near Mansfield.
BENNETT, J. T., Silkstone and Haigh Moor Collieries, Allerton Bywater, Castleford.
BENSON, JAMES R., West Longrigg, Airdrie, N.B.
BENSON, J. G., 12, Grey Street, Newcastle-upon-Tyne.
BENSON, T. W., 11, Newgate Street, Newcastle-upon-Tyne.
BENSON, W. A., Silverdale, Staffordshire.
BERKLEY, C., Marley Hill, Swalwell, R.S.O., Co. Durham.
BERKLEY, FREDERICK, Hamsterley Colliery, Ebchester, R.S.O., Co. Durham.
BERKLEY, R. W., Marley Hill, Swalwell, R.S.O., Co. Durham.
BESWICK, ROBERT, Chell Collieries, Tunstall, Staffordshire.
BEVER, AUGUSTUS, Dewsbury Foundry, Dewsbury.
BEVERIDGE, DAVID, Shiels Farm, Kelty Colliery, Blairadam, Kinross-shire.
BEVERIDGE, JAMES, Linlithgow Oil Company, Linlithgow, N.B.
BEWICK, T. J., Broad Street House, Old Broad Street, London, E.C.
BEYNON, J. C. S., P.O. Box 1364, Johnannesburg, Transvaal.
BIBBY, WM., The Raub Australian Gold Mining Co., Limited, Raub, Pahang, Malay Peninsula.
BIGG-WITHER, H., 10, Swinley Road, Wigan, Lancashire.
BIGGE, D. SELBY, 27, Mosley Street, Newcastle-upon-Tyne.
BIGLAND, J., Henknowle, Bishop Auckland.
BILGRAMI, SYED ALI SHAMSUL ULAMA, Director-General of Mines, Hyderabad, Deccan, India.
BINNS, G. J., Netherseal Colliery, Burton-upon-Trent.
BIRRELL, WILLIAM, Donibristle Colliery, Crossgates, R.S.O., Fifeshire.
BISHOP, GEORGE A., Gartverrie Fireclay Works, Glenboig, Coatbridge, N.B.
BISHOP, JAMES, Grey Valley Coal Co., Brunnerton, Greymouth, New Zealand.
BITZOS, N. J.

BLACK, DONALD, 136, Almada Street, Hamilton, N.B.
BLACK, W., 1, Lovaine Place, Newcastle-upon-Tyne.
BLACKADDER, ALEX, Stand Colliery, Airdrie, N.B.
BLACKBURN, W. STEVENSON, Aive Villas, Astley, Woodlesford, near Leeds.
BLACKETT, W. C., Acorn Close, Sacriston, Durham.
BLACKWOOD, JAMES, 6, Lamb Street, Hamilton, N.B.
BLAKELEY, A. B., Soothill Wood Colliery, Batley.
BLAKEMORE, W., Dominion Coal Company, Limited, Glace Bay, Cape Breton, Canada.
BLANE, ROBERT, P.O. Box 435, Johannesburg, Transvaal.
BLANE, W., P.O. Box 435, Johannesburg, Transvaal.
BLYTH, ARCHIBALD, Park Road, Hamilton, N.B.
BOLAM, PHILIP, North Walbottle Colliery, Newcastle-upon-Tyne.
BOLTON, EDGAR ORMEROD, Executor of Col. Hargreaves, Colliery Offices, Burnley.
BOLTON, H. H., Newchurch Collieries, near Manchester.
BONSER, HAROLD, 39, Hanover Square, Leeds, near Mansfield.
BOOKER, E. E., Warsop Main Colliery, near Mansfield.
BOOLE, GEORGE, The Lodge, Rainford, near St. Helen's, Lancashire.
BOOTH, J. T., Longstile, Talke, Stoke-upon-Trent.
BORLASE, W. H., Brown How, Ulleswater, Glenridding, near Penrith.
BORROWMAN, JAMES, Armadale Station, Linlithgowshire.
BOUCHER, A. S., Kempsey House, near Worcester.
BOULTON, WILLIAM, Burslem, Stoke-upon-Trent.
BOWEN, J., Cleveland House, Wellington Road, Bilston.
BOWIE, HUNTER, Lugar Iron Works, Old Cumnock, N.B.
BOWIE, KENNETH McK., Priory Hill House, Canonbie, N.B.
BOWIE, W. T., 90, Dobbie's Loan, Glasgow.
BOWLER, LOUIS P., Box 105, Barberton, South Africa.
BOWMAN, ARCHD., Jun., Percival Cottage, Buckhaven, Fife.
BOYD, ADAM A., Newcastle Wallsend Coal Company, Wallsend, New South Wales.
BRADFORD, GEORGE, Norton Palms, Darlington.
BRADLEY, RICHARD, Victoria Foundry, Wakefield.
BRAGGE, G. S., Granville Colliery, Swadlincote, Burton-upon-Trent.
BRAIN, F., Trafalgar House, Drybrook, Gloucester.
BRAMLEY, GEORGE, Clay Cross Works, Chesterfield.
BRAMWELL, HUGH, Great Western Colliery, near Pontypridd, Glamorganshire.
BRAND, MARK, Barrhill Cottage, Twechar, Kilsyth, Glasgow.
BREAKELL, THOMAS, Brassington, near Derby.
BRECKON, J. R., 53, John Street, Sunderland.
BREWIS, GEORGE, Boythorpe Colliery, Chesterfield.
BRIDGETT, WILLIAM, Berry Hill Collieries, Stoke-upon-Trent.
BRIERLEY, W., Carlinghow Colliery Co., Carlinghow Lane, Batley.
BRITTEN, T. J., P.O. Box 494, Johannesburg, Transvaal.
BRITTON, ARTHUR, Park Lane, Wigan.
BROJA, RICHARD, 77, Kaiser-Wilhelmstrasse, Breslau, Germany.
BROMLY, A. H., 359, Amhurst Road, Stoke Newington, London, N.
BROOKE, ED., Edgerton, near Huddersfield.
BROOM, ROBERT, Kirkwood Colliery, Bargeddie, N.B.
BROUGH, BENNETT H., c/o Iron and Steel Institute, 28, Victoria Street, London, S.W.

BROUGH, THOMAS, New Seaham Colliery, Sunderland.
BROUGHALL, J., Bushbury View, Prestwood Road, Wolverhampton.
BROWN, ADAM, Allanton Colliery, Hamilton, N.B.
BROWN, A. T., 372, Flinders Lane, Melbourne, Australia.
BROWN, E., St. John's Colliery, Normanton.
BROWN, F., 57, Bridge Street, Walsall.
BROWN, GEORGE, Longriggend Colliery, Airdrie, N.B.
BROWN, JAMES O., 19, Waterloo Street, Glasgow.
BROWN, JOHN, Bridgeness, Bo'ness, R.S.O., Linlithgowshire.
BROWN, M. WALTON, 5, Lambton Road, Newcastle-upon-Tyne.
BROWN, THOMAS, Westport Coal Co., Millerton, Westport, New Zealand.
BROWN, THOS. FORSTER, Guildhall Chambers, Cardiff.
BROWN, THOMAS M., Lanemark Colliery, New Cumnock, R.S.O., Ayrshire.
BROWN, WESTGARTH F., Fairview, Dynas Ponzo, near Cardiff.
BROWN, WILLIAM, The Woodhouse, Bishopbriggs, N.B.
BROWN, WILLIAM, Lathallan Colliery, St. Andrews, N.B.
BROWNE, Sir BENJAMIN C., Westacres, Benwell, Newcastle-upon-Tyne. Transactions to Public Libraries, Newcastle-upon-Tyne.
BROWNE, JAMES T., Griff Colliery, Nuneaton.
BROWNE, R. J., Barakar, East India Railway, Bengal.
BRUCE, JOHN, Port Mulgrave, Hinderwell, R.S.O., Yorkshire.
BRUNT, JAMES, Park Road, Fenton, Stoke-upon-Trent.
BRUNTON, THOMAS, Gray Street, Shotts, N.B.
BRYHAM, W., Douglas Bank Collieries, Wigan.
BUCHANAN, JOHN, Palacecraig Colliery, Airdrie, N.B.
BUCKLEY, FRANK ERNEST, 41A, Victoria Buildings, Manchester.
BUGLASS, JOHN, Stobswood, *via* Acklington, Northumberland.
BULKLEY, F. G., Denver, Colorado, U.S.A.
BULLOCK, J., Bridge Street, Walsall.
BULMAN, E. H., P.O. Box 96, Klerksdorp, South Africa.
BULMAN, H. F., Byer Moor, Burnopfield, near Newcastle-upon-Tyne.
BUNKELL, H. B., P.O. Box 1463, Johannesburg, Transvaal.
BUNNING, C. Z., c/o The Borax Co., Limited, 2, Macri Khan, Constantinople.
BUNTINE, HUGH P., Viewfield Place, Dunfermline, N.B.
BURGESS, JAMES, Burnfoot, Patna, Ayr, N.B.
BURGIN, HENRY, 28, Stead Street, Eckington, Sheffield.
BURLS, HERBERT T., Southdene, Sydenham, London, S.E.
BURN, F. H., Westcliffe, Gosforth, Newcastle-upon-Tyne.
BURN, JAMES, 28, Fawcett Street, Sunderland.
BURNETT, CUTHBERT, Fallowfield House, South Hetton.
BURNS, DAVID, Scotland Road, Stanwix, Carlisle.
BURNS, JAMES, Newbyers Cottage, Gorebridge, R.S.O., Midlothian.
BURROWS, J. S., Green Hall, Atherton, near Manchester.
BURT, HUTCHISON, Shottstown, Penicuik, N.B.
BUTTERLEY, WILFRED, Fountain & Burnley's Thorp's Gawber Collieries, Darton, Barnsley.
BUTTERS, CHARLES, P.O. Box 1891, Johannesburg, Transvaal.
BYRNE, JNO. WALTER, 81, Lichfield Street, Hanley, Staffordshire.

CADELL, H. M., Grange, Bo'ness, R.S.O., Linlithgowshire.
CADMAN, JAMES C., Silverdale Collieries, Newcastle, Staffordshire.

CAINCROSS, JOHN M., Langloan Iron Works, Coatbridge, N.B.
CALDERWOOD, ROBT., Fifeshire Main Collieries, Limited, Oakley, Dunfermline.
CALDWELL, HUGH, Oak House, Blackwood, near Newport, Monmouthshire.
CALDWELL, JAMES, Pumpherston, Mid-Calder, N.B.
CAMERON, IAN, Sudbury, Ontario, Canada.
CAMPBELL, H. H., Sutton Hall, St. Helen's, Lancashire.
CAMPBELL, W. YOUNG, P.O. Box 357, Johannesburg, Transvaal.
CAMPBELL-JOHNSTON, R. C., P.O. Box 40, Vancouver, British Columbia.
CANDLER, T. E., East Lodge, Crook, *via* Darlington.
CAPELL, REV. G. M., Passenham Rectory, Stony Stratford.
CARLOW, CHAS., The Fife Coal Company, Leven, Fife.
CARNES, CHARLES SPEARMAN, Cornwall House, Murton Colliery, Sunderland.
CARR, THOMAS, Lilywhite Terrace, Four Lane Ends, Hetton-le-Hole, R.S.O., Co. Durham.
CARRALL, J. W., Acting Commissioner of the Amoy Customs, Amoy, China.
CARRINGTON, ARTHUR, Langdale House, Clapham Road, Bedford.
*CARRINGTON, T., Kiveton Park Collieries, Sheffield.
CAZALET, L. P., Knight's Tribute Syndicate, Johannesburg, Transvaal.
CHALLINOR, CHARLES, Underwood, near Eccleshall, Staffordshire.
CHALMERS, GEORGE, Superintendent of the St. John del Rey Mining Co., 28, Tower Chambers, Finsbury Pavement, London, E.C.
CHALMERS, J. A.,
CHAMBERS, ALFRED, Eastwood, Notts.
CHAMBERS, A. M., Thorncliffe Collieries, near Sheffield.
CHAMBERS, FRED., Sheffield Road, Woodhouse, Sheffield.
CHAMBERS, GRANVILLE, Digby Collieries, Gilt Brook, Newthorpe, Notts.
CHAMBERS, ISAAC, Watnall Colliery, Nottingham.
CHAMBERS, J. E., Tinsley Collieries, Sheffield.
CHAMBERS, J. E. F., The Hurst, Alfreton.
CHAMBERS, WM., Brinsley Colliery, Eastwood, Notts.
CHAMBERS, WM. HY., Conisborough, Rotherham.
CHAMBERS, W. HOOLE, Tankersley Colliery, near Barnsley.
CHANDLER, N., Hednesford, Staffordshire.
CHANDLEY, CHARLES, c/o E. Graham Price, Woodward Street, Coolgardie, Western Australia.
CHANNING, J. PARKE, 34, Park Place, New York City, U.S.A,
*CHAPMAN, A. C., 29, St. Nicholas' Buildings, Newcastle-upon-Tyne.
CHAPMAN, H. R., Victoria Works, Gateshead-upon-Tyne.
CHAPMAN, W. H., Alma House, Colley Gate, Cradley, Staffordshire.
CHARLETON, A. G., 5, Avonmore Road, Kensington, London, W.
CHARLTON, W., Linares, Provincia de Jaen, Spain.
CHARLTON, WILLIAM, Alpine Villas, Bloxwich Road, Walsall.
CHATER, JOSEPH, Bengal Nagpur Coal Company, Limited, Evelyn Lodge, Kumarpur, Asansol, Bengal, India.
CHEESMAN, E. T., Shire Moor Colliery, Newcastle-upon-Tyne.
CHEESMAN, HERBERT, Hartlepool.
CHEESMAN, I. T., Throckley Colliery, Newcastle-upon-Tyne.
CHEESMAN, W. T., Hartlepool.
CHESTER, P. M., Oakwell Colliery, Ilkeston.
CHICKEN, LANCELOT W., Boldon Colliery, Co. Durham.
CHILDE, HENRY S., Wakefield.

CHRYSTLE, THOMAS, Longton Hall Colliery, Longton, Staffordshire.
CLARK, C. F., Garswood Coal and Iron Co., Limited, near Wigan.
*CLARK, CHARLES JEFFERSON, c/o Messrs. Partridge and Jarvis, 3, Copthall Buildings, London, E.C.
CLARK, GEORGE, Newton-in-the-Willows, Lancashire.
CLARK, JAMES, Tynebank House, Ormiston, Haddingtonshire.
CLARK, JOHN, Dunnikeir Colliery, Kirkcaldy, N.B.
CLARK, JOHN, The Grove, Aldercar, Langley Mill, Notts.
CLARK, ROBERT, Hyderabad (Deccan) Company, Limited, Secundarabad, East India.
CLARK, R. B., Springwell Colliery, Gateshead-upon-Tyne.
CLARK, WILLIAM, 208, St. Vincent Street, Glasgow.
CLARK, W. F., The Poplars, Aldridge, near Walsall.
CLARKE, E. B., 38, Norfolk Street, Sheffield.
CLARKE, JAMES A., Ayr Colliery, Annbank, R.S.O., Ayrshire.
CLARKE, T. B. A., Tankersley Colliery, Tankersley, Barnsley.
CLAUDET, ARTHUR C., 6 and 7, Coleman Street, London, E.C.
CLAUGHTON, G. H., The Priory, Dudley, Worcestershire.
CLAYTON, C. D., Doncaster.
CLAYTON, W. W., c/o Messrs. Hudswell, Clarke, and Co., Loco. Builders, Leeds.
CLELLAND, JAMES, Carronhall Colliery, Falkirk, N.B.
CLIFFORD, WM., Pittsburg, Pa., U.S.A.
CLIVE, ROBERT C., Clanway Colliery, Tunstall, Staffordshire.
CLOUGH, JAMES, Bomarsund House, Bomarsund, Bedlington, R.S.O.
COATS, WILLIAM A., Skelmorlie Castle, Skelmorlie, R.S.O., Ayrshire.
COBBOLD, C. H., Wentworth Castle, Barnsley.
COCHRANE, B., Aldin Grange, Durham.
COCHRANE, C., Green Royde, Pedmore, near Stourbridge.
COCHRANE, W., St. John's Chambers, Grainger Street West, Newcastle-upon-Tyne.
COCKSON, CHARLES, Ince Coal and Cannel Company, Ince, Wigan.
COGHLAN, F. M., Catorce, S.L.P., Mexico.
COHEN, E. H. A., P.O. Box 168, Barberton, Transvaal, South Africa.
COKE, G. E., 65, Station Street, Nottingham.
COLE, JOHN H., Knypersley, Biddulph, near Congleton.
COLE, ROBERT HEATH, Endon, Stoke-upon-Trent.
COLLINS, ARTHUR LAUNCELOT, 14 and 15, Broad Street Avenue, London, E.C.
COLLINS, HORATIO P.O. Box 735, Johannesburg, Transvaal.
COLLINS, H. B., Garscaddin, by New Kilpatrick, Dumbartonshire.
COLLIS, W. B., Stourbridge, Worcestershire.
COLQUHOUN, JAMES, 22, Airdriehill Street, Rawyards, Airdrie, N.B.
COLQUHOUN, T., 36, Sidney Grove, Newcastle-upon-Tyne.
COMMANS, R. E., 6, Queen Street Place, London, E.C.
COOK, J., Washington Iron Works, Washington, Co. Durham.
COOK, J. W., Greenfield House, Crook.
COOKSEY, J. H., Lombard Street, West Bromwich.
CORBETT, V. W., Chilton Moor, Fence Houses.
CORBITT, M.,
CORBOULD, W. H., The Hannan's Reward Gold Mining Company, Limited, Hannans Hill, Kalgoorlie, Western Australia.
CORLETT, G. S., Wigan.
COTTERELL, O. J., 16, Bank Street, Sheffield.

COULSON, FRANK, 10, Victoria Terrace, Durham.
COULTAS, FRED., Deepcar, near Sheffield.
COULTHARD, FRANCIS, Minas del Penoncillo, Marbella, Provincia de Malaga, Spain.
COWAN, JAMES, Cadzow Colliery, Hamilton, N.B.
COWIE, ARCHIBALD D., Alma Vale, Airdrie, N.B.
COWLISHAW, W. G., Etruria, Stoke-upon-Trent.
COX, J. H., 10, St. George's Square, Sunderland.
COX, S. HERBERT, 13, St. Helen's Place, London, E.C.
CRADOCK, G., Rope Works, Wakefield.
CRAIG, W. Y., Milton House, Alsager, Cheshire.
CRAVEN, HIRAM, Jun., Mechanical Engineer, Sunderland.
CRAVEN, JOHN, Westgate Common, Wakefield.
CRAWSHAW, C. B., The Collieries, Dewsbury.
CREEKE, ROBERT B., Durie Foundry, Leven.
CRESWICK, A. J., Gatefield, Sheffield.
CRESWICK, W., Sharlestone Colliery, Normanton.
CRICHTON, A. H., Hillside, Linlithgow, N.B.
CRICHTON, HUGH, Bute House, Airdrie, N.B.
CRIGHTON, JOHN, Union Iron Works, Stewart Street, Stockport.
CROMPTON, GEORGE, Stanton Hall, Nottingham.
CRONE, E. W., Killingworth, near Newcastle-upon-Tyne.
CRONE, J. R., Tudhoe House, *via* Spennymoor.
CRONE, S. C., Oakhurst North, Longbenton, Newcastle-upon-Tyne.
CROOKSTON, ANDREW, Wemyss Colliery, East Wemyss, R.S.O., Fife.
CROOKSTON, A. W., 19, Wellington Street, Glasgow,
CROSBY, GEORGE, Croft House, Featherstone, Pontefract.
CROSS, JOHN, 77, King Street, Manchester.
CROUDACE, C. J., Bettisfield Colliery Co., Limited, Bagillt, North Wales.
CROUDACE, FRANK, The Scottish Australian Mining Company, Limited, Lambton, Newcastle, New South Wales.
CROUDACE, T., West House, Haltwhistle.
CROUDACE, THOMAS, Lambton Lodge, Lambton, Newcastle, New South Wales.
CURRIE, WALTER, P.O. Box 220, Buluwayo, Rhodesia, South Africa.
CURRY, W. THOS., Wentwood, near Caerleon, Monmouthshire.
CUTHBERTSON, JOHN, Thomson Street, Kilmarnock, N.B.

DACRES, THOS., Reitz Street, Kimberley, South Africa.
DAGLISH, JOHN, Rothley Lake, Cambo, R.S.O., Northumberland.
DAKERS, W. R., The Loggins, Tudhoe Colliery, *via* Spennymoor.
DALE, Sir DAVID, Bart., West Lodge, Darlington.
DALZELL, JOHN B., Larkhall, N.B.
DANIEL, P. F., Greymouth, New Zealand.
DANKS, ANDREW, Duntilland Colliery, Holytown, N.B.
DARBY, G. M., Katras Kerria Coal Co., Limited, Katras P.O., *via* Burrakur, India.
DARBY, JOHN H., Brymbo, near Wrexham.
DARLING, FENWICK, South Durham Colliery, Darlington.
DARLINGTON, JAMES, Black Park Colliery, Ruabon, North Wales.
DAVEY, GEO., 111, Windmill Street, Gravesend.
DAVEY, HENRY, 3, Princes Street, Westminster, London, S.W.
DAVIES, ALFRED, Engineering Works, Burton-upon-Trent.

*Davies, D. E., Cwmaman Colliery, Aberdare.
Davies, Lt.-Col. Jasper G. S., Marton, Middlesbrough.
Davies, John, Hartley House, Coundon, Bishop Auckland.
Davies, J. Hubert, P.O. Box 455, Johannesburg, Transvaal.
Davies, Morgan W., 17, Adelaide Street, Swansea.
Davies, T. J., Balls Hill, West Bromwich.
Davies, Watkin, Renishaw Foundry and Engineering Works, Chesterfield.
Davies, W. J., Bradley, Bilston.
Davis, Henry, All Saints Works, Derby.
Davis, Kenneth, Dudley Colliery, Northumberland.
Davison, J. Ford, Yarlside, Dalton-in-Furness.
Daw, John, Jun., Brooklands, Rosemont Road, Acton, London, W.
Dawbarn, A. G., 60, Gracechurch Street, London, E.C.
Dawson, G. J. Crosbie, Newcastle-under-Lyme, Staffordshire.
Deacon, Maurice, Blackwell Collieries, Alfreton.
Dean, Arthur, Waterloo Road, Burslem, Stoke-upon-Trent.
Dean, William, Ince Hall Collieries, near Wigan.
Dearden, Jos., The Knowl, Tinsley, near Sheffield.
Dees, J. Gibson, Floraville, Whitehaven.
Dees, R. R., Newcastle-upon-Tyne.
Delprat, G. D., Campanas No. 15, Cordoba, Spain.
Denny, G. A., Klerksdorp Proprietary Mines, Limited, Klerksdorp, S.A.R.
Devonshire, The Duke of, K.G., Chatsworth, Baslow, Derbyshire.
Dewar, Thomas, Clydesdale Collieries, Springs, Johannesburg, Transvaal.
Dickenson, Charles, Northenden, Manchester.
Dickinson, Arthur, Warham Road, South Croydon, Surrey.
Dickinson, George W., Eckington Collieries, near Sheffield.
Dixon, D. W., Lumpsey Mines, Brotton, R.S.O., Saltburn-by-the-Sea.
Dixon, James S., Fairleigh, Bothwell, N.B.
Dixon, Jonathan, Maitland Street, Stockton, *via* Newcastle, New South Wales.
Dixon, Walter, 164, St. Vincent Street, Glasgow.
Dobb, T. G., Derby Terrace, Hindley, near Wigan, Lancashire.
Dobbs, Joseph, Jarrow Colliery, Castlecomer, Co. Kilkenny.
Dobinson, Lancelot, Victoria Coal Company, Park Hills Colliery, Wakefield.
Dodd, B., Bearpark Colliery, near Durham.
Dodd, M., Burncroft, Hexham.
Dodd, T. R., P.O. Box 818, Johannesburg, Transvaal.
Donald, A. W., 5, West Regent Street, Glasgow.
Donaldson, Robert, Clyde Iron Works, Tollcross, Glasgow.
Donkin, W., c/o A. M. Appleton, West End, Sedgefield.
Douglas, A. S., Hucknall Torkard, Nottingham.
Douglas, C. P., Thornbeck Hill, Carmel Road, Darlington.
Douglas, John, 4, Brandling Terrace, Felling, R.S.O., Co. Durham.
Douglas, M. H., Usworth Colliery, Washington, R.S.O., Co. Durham.
Douglas, T., The Garth, Darlington.
Dowdeswell, H., Butterknowle Colliery, *via* Darlington.
Doyle, Patrick, *Indian Engineering*, 19, Lall Bazaar, Calcutta, India.
Draper, David, P.O. Box 460, Johannesburg, South African Republic.
Drinnan, Walter, Waveley Coal Company, Darnall, Sheffield.
Dron, R. W., 79, West Regent Street, Glasgow.

DUDLEY, URIAH, P.O. Box 110, Broken Hill, New South Wales.
DUMAT, ALFRED, 1, Loop Street, Pietermaritzburg, Natal.
DUNBAR, C., St. Ann's Terrace, The Common, Bolton-upon-Dearne, Rotherham.
DUNDAS, EDMUND, Union Gold Mining Company, Limited, Barberton, Transvaal.
DUNLOP, COLIN, Quarter Collieries, Hamilton, N.B.
DUNLOP, COLIN JOHN, Quarter Collieries, Hamilton, N.B.
DUNN, DAVID G., Coilsholm, Cambuslang, Glasgow.
DUNN, ROBERT, 168, Kenmure Street, Pollokshields, Glasgow.
DUNN, WILLIAM L., 183, West George Street, Glasgow.
DUNSIRE, ANDREW, 66, Main Street, Lochgelly, R.S.O., Fifeshire.
DURNFORD, H. ST. JOHN, Ackton Hall Colliery, Featherstone, near Pontefract.
DUTSON, JOHN, Orgreave Colliery, near Sheffield.
DYSON, JOHN S., Kirkburton, Huddersfield.
DYSON, T. I, Mount Morgan, *via* Rockhampton, Queensland.

EARDLEY, EDWIN, 7, Wilson Street, Derby.
EARDLEY, J. W., The Grove, Alfreton.
EASTLAKE, A. W., Balham, London.
EASTWOOD, EDWARD, Railway Wagon Works, Chesterfield.
EASTWOOD, G. A., Tapton Villa, Chesterfield.
EDEN, C. H., c/o Messrs. Vivian and Sons, Swansea.
EDGE, J. H., Coalport Wire Rope and Chain Works, Shifnal, Salop.
EDGE, J. WILCOX, Burslem, Stoke-upon-Trent.
EDWARDS, EDWARD, Maindy Pit, Ocean Collieries, Ton Pentre, Glamorganshire.
ELCE, GEORGE, Clayton-le-Moors, Accrington, Lancashire.
ELCE, JAMES, Woodland Villas, Ince Green Lane, Wigan.
ELEY, J. J., Snydale Collieries, near Pontefract.
ELLIOTT, WILLIAM, Blackwell Collieries, Alfreton.
ELLIS, W. R., Wigan.
ELSDON, ROBERT, The Highlands, Burnt Ash Hill, Lee, Kent.
ELWEN, THOMAS LEE, Littleburn Colliery, near Durham.
EMBLETON, H. C., Central Bank Chambers, Leeds.
EMBLETON, T. W., The Cedars, Methley, Leeds.
EMINSON, J. B., Londonderry Offices, Seaham Harbour.
EPTON, W. MARTIN, P.O. Box 737, Johannesburg, Transvaal.
ETHERINGTON, J., 39A, King William Street, London Bridge, London, E.C.
EVANS, E. W., 7, Oakbank Avenue, Chorlton-cum-Hardy, Manchester.
EVANS, LEWIS, P.O. Box 2691, Johannesburg, Transvaal.
EVERARD, J. B., 6, Millstone Lane, Leicester.
EVERSON, CHARLES, Sheepbridge Colliery Offices, near Chesterfield.

FAIRLEY, JAMES, Craghead and Holmside Collieries, Chester-le-Street.
FALLOWS, WM., Arbury Road, Nuneaton.
FARMER, A., Seaton Carew, near West Hartlepool.
FARNWORTH, W., Manor House, Sedgley, near Dudley, Worcestershire
FAULDS, ALEXANDER, Steel Works, Calderbank, N.B.
FAVELL, THOMAS MILNES, Heatherlea, Wolstanton, Stoke-upon-Trent.
FEARN, J. W., Devonshire Street, Chesterfield.
FENN, ABRAHAM, Tame Valley Colliery, Wilnecote, Tamworth.
FENNELL, CHAS. W., 17, Wood Street, Wakefield.

FENWICK, BARNABAS, 84, Osborne Road, Newcastle-upon-Tyne.
FENWICK, P. J., The Sutton Colliery Company, Ltd., Sutton-in-Ashfield, Notts.
FENWICK, T. E., Mayfield, Wolsingham, near Darlington.
FERENS, FREDERICK J., Silksworth Colliery, Sunderland.
FERENS, F. S., 13, Railway Arches, Westgate Road, Newcastle-upon-Tyne.
FERGIE, CHARLES, Drummond Colliery, Westville, Nova Scotia.
FERGUSON, D., c/o James Ferguson, 115 Buccleuch Street, Garnethill, Glasgow.
FERGUSON, PETER, 19, Royal Exchange Square, Glasgow.
FIELD, J., Hill Top, West Bromwich.
FIGARI, ALBERTO, Apartado No. 255, Lima, Peru.
FINDLAY, G. J., Broughton and Plas Power Collieries, near Wrexham.
FISHER, E. R., Nant Glas, Cross Hands, near Llanelly, South Wales.
FISHER, HENRY, Clifton Colliery, Nottingham.
FISHER, ROBERT, Dechmont Colliery, Newton, N.B.
FISHER, THOMAS T., Lichfield Chambers, Walsall.
FISHWICK, R., Binchester Colliery, Co. Durham.
FITTON, GEORGE, Highfield House, Beeston, near Leeds.
FLEMING, C. E., 71, Elswick Road, Newcastle-upon-Tyne.
FLEMING, DAVID, East Plean Colliery, Bannockburn, N.B.
FLETCHER, JAMES, Wickham and Bullock Island Coal Company, Limited, Carrington, New South Wales.
FLETCHER, LANCELOT, Brigham Hall, Carlisle.
FLETCHER, WALTER, The Hollins, Bolton, Lancashire.
FLINT, JOHN, Broomhill Colliery, Acklington, Northumberland.
FOGGIN, W., 12, Devonshire Place, Jesmond, Newcastle-upon-Tyne.
FOGGO, W., The Glen, Brereton, Rugeley.
FORBES, ALEXANDER, Glebe Street, Bellshill, N.B.
FORBES, ALEXANDER, 4, Killoch Place, Ayr, N.B.
FORD, C. F. V., Marehay Main Colliery, Ripley, Derby.
FORD, JAS., Hotel Street, Coalville, near Leicester.
FORD, MARK, Sherburn Colliery, near Durham.
FORD, STANLEY H., P.O. Box 2056, Johannesburg, Transvaal.
FORGIE, JAMES T., Bothwell Collieries, Bothwell, Glasgow.
FORREST, J. C., Holly Bank Colliery, Essington, Wolverhampton.
FORRESTER, H. C., Gavell House, Kilsyth, Glasgow.
FORRESTER, ROBERT, Salt Lake City, Utah, U.S.A.
FORSTER, G. B., Farnley Hill, Corbridge-upon-Tyne.
FORSTER, J. R., Water Company's Office, Newcastle-upon-Tyne.
FORSTER, T. E., 3, Eldon Square, Newcastle-upon-Tyne.
FORSYTH, JAMES, Parkfoot, Falkirk, N.B.
FORSYTH, WM., Glenclelland House, Wishaw, N.B.
FOSTER, GEO., Lyme House, Rotherham.
FOSTER, GEORGE, Osmondthorpe Colliery, Leeds.
FOULSTONE, W., Coach and Horses Hotel, Barnsley.
FOWLER, GEORGE, Basford Hall, Nottingham.
FOWLER, R., Washington Colliery, Washington Station, R.S.O., Co. Durham.
FOWLER, W. C., Beeston, Notts.
FRECHEVILLE, WM., Claremont, Nutfield, Redhill, Surrey.
FRENCH, JOHN, Millcroft Cottage, Rutherglen Road, Glasgow.
FREW, HENRY, Broomhouse Colliery, Broomhouse, N.B.
FREW, JAMES, 5, Greenhill, Dunaskin, Ayr, N.B.

FREW, JAMES, 75, Bath Street, Glasgow.
FREW, ROBERT, 75, Bath Street, Glasgow.
FREW, WILLIAM, Broomhouse Colliery, Broomhouse, N.B.
FROSSARD, J. D., c/o Messrs. Fry, Everitt, and Co., 7, Cambrian Place, Swansea.
FROST, WILLIAM, Sneyd Colliery, Burslem, Stoke-upon-Trent.
FRYAR, MARK, Denby Colliery, Derby.

GALLOWAY, ROBERT L., 43, Mair Street, Plantation, Glasgow.
GALLOWAY, T. LINDSAY, Argyll Colliery, Campbeltown, N.B.
GALLOWAY, W., Cardiff.
GALLWEY, A. PAYNE, P.O. Box 138, Johannesburg, Transvaal.
GARDINER, EDGAR T., 8, South View Terrace, Bishop Auckland.
GARDNER, HUGH, Minas Schwager, Coronel, Chili.
GARFORTH, W. E., West Riding Colliery, Normanton.
GARSIDE, F., Wath Main Colliery, near Rotherham.
GARVEN, WILLIAM, 14, Lorne Terrace, Maryhill, Glasgow.
GATER, ENOCH, Oak Tree Cottage, Talke, Stoke-upon-Trent.
GAVIN, JAMES, Udston Colliery, Hamilton, N.B.
GEDDES, GEORGE H., 142, Princes Street, Edinburgh.
GEMMELL, JOHN, 10, St. Andrew's Square, Edinburgh.
GEMMELL, ROBERT, Hopetown Works, Winchburgh, Linlithgowshire.
GERRAND, JOHN, Crown Reef Gold Mining Company, Johannesburg, Transvaal.
GERRARD, JAMES, 11, Meek's Buildings, Wigan.
GERRARD, JOHN, H.M. Inspector of Mines, Worsley, near Manchester.
GIBB, ROBERT, Glyncorwg, Cymmer, R.S.O., South Wales.
GIFFORD, G. GRAVES, Chancery Chambers, Hunt Street, Coolgardie, Western Australia.
GIFFORD, HENRY J., Minas de Passagem, Ouro Preto, Brazil.
GILCHRIST, JAMES, Lanemark Colliery, New Cumnock, R.S.O., Ayrshire.
GILCHRIST, J. R., Garesfield Colliery, Lintz Green, Newcastle-upon-Tyne.
GILL, JOHN, Lofthouse Colliery, Wakefield.
GILL, THOMAS, Strafford Collieries, near Barnsley.
GILLESPIE, ALEXANDER, Dalmellington Iron Works, Ayr, N.B.
GILLETT, L. F., 163, Osmaston Road, Derby.
GILLMAN, F., Gartenstrasse, 1, Freiburg in/B., Baden, Germany.
GILLOTT, J. W., Summer Lane, Barnsley.
GILMOUR, ALLAN, Portland Colliery, Kilmarnock, N.B.
GILROY, S. B., Markham Collieries, Duckmanton.
GIPPS, F. G. DE VISME, Coolgardie, Western Australia.
GJERS, JOHN, 3, Southfield Villas, Middlesbrough.
GLEDHILL, EDWARD, Carolina Hacienda, Honda, Republic of Colombia, South America.
GLEN, JOHN, Connell Terrace, Airdrie, N.B.
GLENNIE, W. H., Minas de Rosario, Nieves, Estado de Zacatecas, Mexico.
GOLDSWORTHY, ARTHUR, Linares, Provincia de Jaen, Spain.
GOODWIN, G. A., Roodeport, Witwatersrandt, South Africa.
GOODWIN, WILLIAM H., Chesterton Hall, Apedale, Staffordshire.
GOOLDEN, WALTER T., c/o Messrs. Easton, Anderson, & Goolden, Ltd., 2, St. Nicholas' Buildings, Newcastle-upon-Tyne.
GORDON, GAVIN C., Netherton, Wishaw, N.B.
GOULDIE, JOSEPH, The Gill, Aspatria, Cumberland.
GRANT, A. M.

GRANT, JOHN, The Grange, Larkhall, R.S.O., Lanarkshire.
GRATTON, R. T., Knifesmith Gate, Chesterfield.
GRAVE, L. W. DE, All Saints Works, Derby.
GRAVES, H. G., 5, Robert Street, Adelphi, London, W.C.
GRAY, ARCHIBALD, Middleton House, Dalry, Ayrshire.
GRAY, ARCHIBALD, Jun., 55, Eglinton Street, Ardrossan, N.B.
GRAY, JAMES, Riverside, Old Cumnock, N.B.
GRAY, JOHN, Morningside Colliery, Newmains, N.B.
GRAY, WILLIAM, Carfin Colliery (Dixon's), Motherwell, N.B.
GRAY, WILLIAM, Common Cottage, Auchinleck, R.S.O., Ayrshire.
GRAYSTON, F. A., Glascote House, Tamworth.
GREATBACH, GEORGE H., Great Fenton Collieries, Stoke-upon-Trent.
GREAVES, J. O., Westgate, Wakefield.
GREAVES, PERCY C., Westgate, Wakefield.
GREEN, A. T., 1, Whiston Grange, Moorgate, Rotherham.
GREEN, EDWIN R., Abbotsford Colliery, Abbotsford, Dunedin, New Zealand.
GREEN, J. T., Southside, Sneyd Park, Clifton, Bristol.
GREENER, HENRY, South Pontop Colliery, Annfield Plain.
GREENER, T. Y., West Lodge, Crook, Darlington.
GREENSMITH, JOHNSON, Newstead Colliery, Nottingham.
GREENWELL, G. C., Jun., Poynton, near Stockport.
GREENWOOD, W. H., Hardwicke Road, Edgbaston, Birmingham.
GREGORY, AUBREY, Dhadka Colliery, Asansol, E.I.R., India.
GREGORY, H. E., Cartonwood Colliery, Barnsley.
GREGORY, JAS., Jun., Lowood Villas, Deepcar, Sheffield.
GREGSON, G. E., 11, Chapel Street, Preston, Lancashire.
GRESLEY, W. S., Erie, Pennsylvania, U.S.A.
GREY, C. G., Ballycourcy, Enniscorthy, Co. Wexford.
GRIFFITH, ED., Brymbo Colliery, Wrexham, North Wales.
GRIFFITH, N. R., Plasnewydd, Ruabon, North Wales.
GRIFFITHS, F., Pensnett, Dudley, Worcestershire.
GRIFFITHS, W., Waterloo House, Aberystwyth, South Wales.
GRIMSHAW, E. J., 23, Hardshaw Street, St. Helen's, Lancashire.
GUTHRIE, JAMES K., The Terrace, Ovingham-upon-Tyne.

HABERSHON, M. H., Thorncliffe Ironworks and Collieries, Sheffield.
HADDOCK, W. T., Sutherland Reef, Limited, Leydsdorp, Zoutpansberg, South African Republic.
HADDOW, JOHN, Benquhat, Dalmellington, R.S.O., Ayrshire.
HADFIELD, JOSEPH.
HADFIELD, R. A., Hecla Steel Foundry, Sheffield.
HAGGIE, D. H., Wearmouth Patent Rope Works, Sunderland.
*HAGGIE, F. W., Gateshead-upon-Tyne.
HAGGIE, G. A., Wearmouth Ropery, Sunderland.
HAGGIE, PETER SINCLAIR, Gateshead-upon-Tyne.
HAGGIE, R. HOOD, Jun., Box No. 5, Royal Exchange, Glasgow.
HAGUE, ERNEST, Castle Dyke, Sheffield.
HAIGH, WM., Colliery Owner, Dewsbury.
HAINES, J. RICHARD, Adderley Green Collieries, Stoke-upon-Trent.
HALDER, ALBERT H., 6, Drapers Gardens, London, E.C.

HALL, EDGAR, Wharncliffe Silkstone Colliery, Barnsley.
HALL, FRED., Fernleigh, Highfield, Workington.
HALL, FRED. W., Haswell Lodge, Sunderland.
HALL, H. R., Hazel Grove, West Park, Chesterfield.
HALL, JOHN, Sheepbridge Works, Chesterfield.
HALL, JOHN, Swadlincote and Cadley Hill Collieries, Burton-upon-Trent
HALL, L. J., Furness Vale, Stockport.
HALL, M., Lofthouse Colliery, Wakefield.
HALL, M. S., 8, Victoria Street, Bishop Auckland.
HALL, TOM, Ryhope Colliery, *via* Sunderland
HALL, W., Heath End, Pelsall, Wallsall.
HALL, W. F., Haswell Colliery, Haswell, *via* Sunderland.
HALLAS, G. H., Wigan and Whiston Coal Co., Limited, Prescot.
HALLIMOND, W. T., General Manager, Rand Collieries, Limited, Brakpan, Z.A.R.
HALSE, EDWARD, Coolgardie, *via* Albany, Western Australia.
HAMILTON, E., Rig Wood, Saltburn-by-the-Sea.
HAMILTON, G., c/o Messrs. B. S. Lloyd and Co., 78, Queen Victoria Street, London, E.C.
HAMILTON, JAMES, 208, St. Vincent Street, Glasgow.
HAMILTON, JOHN, 18, Orbiston Street, Motherwell, N.B.
HAMILTON, J. P., Bull Bridge Lime Works, Bull Bridge, Derbyshire.
HAMILTON, LORD, Dalzell Estate Office, Motherwell, N.B.
HAMILTON, ROBERT, 88, Great Clyde Street, Glasgow.
HAMILTON, WILLIAM, Niddrie Cottages, Portobello, N.B.
HANCOCK, H. L., Moonta Mines, South Australia.
HANCOCK, H. R., Moonta Mines, South Australia.
HANNAH, DAVID, Ferndale, Glamorgan.
HARDIE, JAMES, Broomknowe, Cambuslang, N.B.
HARDIE, W. D. L., Birmingham, Alabama, U.S.A.
HARDWICK, FRANCIS W., Firth College, Sheffield.
HARDWICK, FREDERICK, Eckington Collieries, Sheffield.
HARE, SAMUEL, Bedlington Collieries, Bedlington, R.S.O., Northumberland.
HARGREAVES, J., Rothwell Haigh Colliery, Leeds.
HARGREAVES, JOSEPH, Gwaun Cae Gurwen Collieries, Brynamman, R.S.O.
HARGREAVES, WALTER, Robin Hood Collieries, Wakefield.
HARGREAVES, WILLIAM, Rothwell Haigh Colliery, Leeds.
HARKER, WM., 17A, Great George Street, Westminster, London, S.W.
HARLE, PETER, Pagebank Colliery, Co. Durham.
HARLE, RICHARD, Browney Colliery, Durham.
HARPER, J. P., All Saints' Chambers, Derby.
HARRIS, G. E., Margherita, Debrugarh, Upper Assam.
HARRIS, W. S., Kibblesworth, Gateshead-upon-Tyne.
HARRISON, C. A., North-Eastern Railway, Newcastle-upon-Tyne.
HARRISON, G. B., H.M. Inspector of Mines, Swinton, near Manchester.
HARRISON, G. D., Waterworks, Hanley, Staffordshire.
HARRISON, S., Fitzwilliam-Hemsworth Collieries, near Wakefield.
HARRISON, W. B., Brownhills Collieries, near Walsall.
HARROP, J. A., Westminster Collieries, Wrexham.
HART, ROBERT, Apedale, near Chesterton, Staffordshire.
HARVEY, WM. PELLEW, Assay Office and Metallurgical Works, Vancouver, British Columbia.
HASSAM, ARTHUR, Flimby and Broughton Moor Collieries, Maryport.

Hassard, W. J., 209, Sauchiehall Street, Glasgow.
Hastie, James, Greenfield Colliery, Hamilton, N.B.
Hawker, Ed. Wm., Adelaide Club, Adelaide, South Australia.
Hawkins, R. Spencer, Ayrshire Mine, Lo Mogundis, Salisbury, Mashonaland, South Africa.
Hay, J., Jun., Widdrington Colliery, Acklington.
Hay, T. Y., Whitwick Colliery, Coalville, Leicester.
Hay, William, Nostell Colliery, Wakefield.
Hay, W., Stanton Colliery, Burton-upon-Trent.
Hayward, W. J., West Bromwich.
Head, James M., Glasgow Rhea Co., Tennessee, U.S.A.
Head, Jeremiah, 47, Victoria Street, Westminster, London, S.W.
Heap, R. S., 2, Nelson Square, Burnley.
Heath, James, 54, Cadogan Square, London, S.W.
Heath, John, Sneyd Colliery, Burslem, Stoke-upon-Trent.
Heath, Robert, Biddulph Valley Iron Works, Stoke-upon-Trent.
Heath, William, Sneyd House, Burslem, Stoke-upon-Trent.
Hedley, J. L., H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
Hedley, Sept. H., Langholme, Roker, near Sunderland.
Hedley, W. H., 34, Beverley Terrace, Cullercoats.
Henderson, H., Pelton Colliery, Chester-le-Street.
Henderson, J. J., Executive Engineer, Shahrigh, Beloochistan, India.
Henderson, J. J., U.S. Engineer's Office, Kingsbridge, New York, U.S.A.
Henderson, William, Levenseat, Fauldhouse, Linlithgowshire.
Hendy, J. C. B., Etherley, *via* Darlington.
Henshaw, A. Mayon, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.
Hepburn, Wheldon, Littletown Colliery, near Durham.
Heppell, T., Leafield House, Birtley, Chester-le-Street.
Hepplewhite, W. H., H.M. Inspector of Mines, Blenheim Mount, St. Ann's Hill, Nottingham.
Herd, Thomas, Dunnikier Colliery, Kirkcaldy, N.B.
Heslop, C., Woodside, Marske Mill Lane, Saltburn-by-the-Sea.
Heslop, Grainger, Deptford Hall, Sunderland.
Heslop, James, Ashfield, Gedling, near Nottingham.
Heslop, Michael, Rough Lea Colliery, Willington, Co. Durham.
Heslop, Septimus, New Beerbhoom Coal Co., Limited, Asansol, Bengal, India.
Heslop, Thomas, Storey Lodge Colliery, Cockfield, *via* Darlington.
Heslop, Wm. Taylor, Central Collieries, Brakpan, Johannesburg, Transvaal.
Hewitt, C. R., London Road, Derby.
Hewitt, G. C., Serridge House, Coalpit Heath, near Bristol.
Hewitt, H. R., H.M. Inspector of Mines, 23, Hartington Street, Derby.
Hewitt, T. P., Castle Gresley, Burton-upon-Trent.
Hewlett, A., Haseley Manor, Warwick.
Hicks, Prof. W. M., Firth College, Sheffield.
Higby, Robert George, c/o F. W. Heilgers & Co., 22, Great St. Helen's, London, E.C.
Higgins, Samuel, Weston Coyney Road, near Longton, Staffordshire.
Higson, Jacob, Crown Buildings, 18, Booth Street, Manchester.
Higson, John, Crown Buildings, 18, Booth Street, Manchester.
Hill, James, Helenbank Cottage, Dalmellington, R.S.O., Ayrshire.
Hill, William, Old Schoolhouse, Dalmellington, R.S.O., Ayrshire.

HILL, WILLIAM, The Pooley Hall Colliery Company, Polesworth, near Tamworth.
HILTON, J., 67, Hawkshead Street, Southport.
HILTON, T. W., Wigan Coal and Iron Co., Limited, Wigan.
HINCHLIFFE, HERBERT, Bullhouse Colliery, Penistone, near Sheffield.
HINCHLIFFE, J., Bullhouse Colliery, Penistone, near Sheffield.
HOBBS, WILLIAM L., Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
HOBSON, J. B., Cariboo Hydraulic Mining Co., Limited, Vancouver, British Columbia.
HODGE, FRANCIS, Coromandel, near Auckland, New Zealand.
HODGES, ISAAC, Blackwell Collieries, Alfreton.
HODGSON, JACOB, Cornsay Colliery, Co. Durham.
HODGSON, J. Edmondsley Colliery, Chester-le-Street.
HODSON, JAMES, The Mount, Thalto Heath, St. Helen's, Lancashire.
HOFFMANN, CHARLES, P.O. Box 1022, Johannesburg, Transvaal.
HOGG, C. E., 1, St. Helen's Place, London. E.C.
HOGG, JAMES, Kirkhill Colliery, Cambuslang, Glasgow.
HOGG, JOHN, Ardoch Grove, Cambuslang, Glasgow.
HOGG, JOHN, Victoria Engine Works, Airdrie, N.B.
HOLBROOK, JOHN, Langley Colliery, Marlpool, Derby.
HOLDING, WILLIAM, Cossall Colliery, Nottingham.
HOLFORD, W. D., Whittington, Chesterfield.
HOLIDAY, ROSLYN, Ackton Hall Colliery, Featherstone, near Pontefract.
HOLLIDAY, MARTIN F., Langley Grove, Durham.
HOLLIDAY, T., 11, Marlborough Grove, Woodhouse Lane, Leeds.
HOLLINGS, JOHN H., Wath Main Colliery, Rotherham.
HOLLINGWORTH, G. W., 12, King Street, Manchester.
HOLLINS, G., High Street, Wolstanton, Stoke-upon-Trent.
HOLLIS, HENRY WM., Whitworth House, Spennymoor.
HOLLOWAY, GEORGE, Hamstead Colliery, Great Barr. Birmingham.
HOLMES, C., 109, Victoria Road, Darlington.
HOLT, JOHN, Jun., 109, Manchester Road, Swinton, Lancashire.
HOMAN, WILLIAM MCLEAN, c/o D. McCall, 10, Rosslyn Terrace, Kelvinside, Glasgow.
HOOD, A., 6, Bute Crescent, Cardiff.
HOOD, JAMES A., Rosewell, Midlothian.
HOOPER, ED., c/o J. H. Hooper, College Precincts, Worcester.
HOOPER, G. C., Whitehaven Collieries, Whitehaven.
HOPKINS, EDWARD, 13, Harrington Gardens, London, S.W.
HOPKINSON, HENRY, Station Street, Nottingham.
HOPKINSON, JOHN, Inglewood, St. Margaret's Road, Bowden, Cheshire.
HORNE, THOMAS L., Twechar Works, Kilsyth, N.B.
HORSFIELD, A., Horbury Junction Iron Works, Wakefield.
HOSKING, JAMES, Roskear, Camborne, Cornwall.
HOSKOLD, H. D., Inspector-General of Mines of the Argentine Republic, and Director of the National Department of Mines and Geology, Buenos Ayres, Argentine Republic.
HOUFTON, CHARLES, Heathfield Villas, Garforth, Leeds.
HOUFTON, J. P., Bolsover Colliery, Chesterfield.
HOUSTON, JAMES, Salsburgh, Holytown, R.S.O., Lanarkshire.
HOWARD, W. F., 15, Cavendish Street, Chesterfield.
HOWAT, ROBERT M., 32, Victoria Street, Westminster, London, S.W

HOWAT, WILLIAM, Rankinston Works, Ayr, N.B.
HOWAT, WILLIAM, Sundrum, Coylton, Ayr, N.B.
HOWDEN, THOMAS, Wakefield.
HOWE, WM., Clay Cross, Chesterfield.
HOWELL, J. C., New Dock, Llanelly, South Wales.
HOWES, FRANK T., Singareni Collieries, Hyderabad Deccan Co., Secundarabad, India.
HOWIE, JOHN, Machan Colliery, Larkhall, R.S.O., Lanarkshire.
HOWIESON, ROBERT, Glebe Park, West Calder, N.B.
HOWL, E., The Quarries, Dudley, Worcestershire.
HUBBERSTY, H. A., Burbage, Buxton.
HUGH, JAMES, Thornhill, Blantyre, Glasgow.
HUGHES, H. W., 188, Wolverhampton Street, Dudley, Worcestershire.
HUGHES, J., Dudley, Worcestershire.
HUGHES, T. VAUGHAN, 35, Paradise Street, Birmingham.
HULL, Prof. E., 20, Arundel Gardens, London, W.
HUMBLE, JOSEPH, Markham Collieries, Duckmanton, Chesterfield.
HUMBLE, WILLIAM, La son Street, Hamilton, Newcastle, New South Wales.
HUNT, WALFORD, Cinder Hill, Nottingham.
HUNTER, ANDREW, Alloa Colliery, Alloa, N.B.
HUNTER, DAVID, 101, St. Vincent Street, Glasgow.
HURLL, MARK, 95, Bath Street, Glasgow.
HURST, GEORGE, 9, Framlington Place, Newcastle-upon-Tyne.
HURST, G. A., Glascote, Tamworth.
HYSLOP, G. P., The Madeley Coal and Iron Company, Limited, Madeley, near Newcastle, Staffordshire.
HYSLOP, JONATHAN, Airdriehouse Cottage, Airdrie, N.B.

IRVINE, JOHN, Bothwell Castle Colliery, Bothwell, N.B.
ISHERWOOD, JONATHAN, Hodroyd Colliery, Barnsley.

JACKSON, DAVID, Glengyron, Old Cumnock, N.B.
JACKSON, DOUGLAS, Coltness Iron Works, Newmains, N.B.
JACKSON, H. H., Colley Gate, Cradley, Staffordshire.
JACKSON, JOHN, Stubben Edge, Chesterfield.
JACKSON, W. B. M., Clay Cross Hall, Chesterfield.
JACKSON, W. G., Hicklam House, Aberford, near Leeds.
JAMIESON, ALEXANDER, Balgonie Colliery, Markinch, N.B.
JAMIESON, J. AULDJO, 66, Queen Street, Edinburgh.
JAMIESON, T. J., Eddlewood Colliery, Hamilton, N.B.
JARRATT, J., Houghton Main Colliery, Barnsley.
JEFFCOCK, C. E., Birley Collieries, Sheffield.
JEFFCOCK, T. W., 18, Bank Street, Sheffield.
JENKINS, W., Ocean Collieries, Treorchy, R.S.O., Glamorganshire.
JEPSON, H., 39, North Bailey, Durham.
JOBLING, T. E., Blyth, Northumberland.
JOHNS, J. HARRY, Ferreira Gold-mining Co., Limited, P.O. Box 1021, Johannesburg, Z.A.R.
JOHNSON, GUY ROCHE, P.O. Box, 75, Embreville, Washington County, Tennessee, U.S.A.
JOHNSON, HENRY, Trindle Road, Dudley, Worcestershire.

JOHNSON, J., The Terrace, Stairfoot, near Barnsley, and Charbonnages de Rodez, Limited, Gages, Avéyron, France.
JOHNSON, W., Abram Colliery, Wigan.
JOHNSON, WM., 3, Elm Grove, Warkworth.
JOHNSTON, D. S., P.O. Box 116, Johannesburg, Transvaal.
JOHNSTON, J. HOWARD, c/o Messrs. Backus and Johnston, Lima, Peru, South America.
JOHNSTONE, HUGH, 77, Montgomery Street, Kelvinside North, Glasgow.
JOHNSTONE, JAMES, Belhaven Road, Wishaw, N.B.
JOHNSTONE, RONALD H., 5, West Regent Street, Glasgow.
JOICEY, J. G., Forth Banks West Factory, Newcastle-upon-Tyne.
JOICEY, W. J., Sunningdale Park, Berks.
JONAS, GEO. B., 15, Gordon Street, Glasgow.
JONES, ENOS, Whitwell Colliery, Whitwell, Chesterfield.
JONES, F. J., Rother Vale Collieries, Treeton, Rotherham.
JONES, ISAAC, Wynnstay Collieries, Ruabon.
JONES, JOHN, Shire Oaks Colliery, Worksop.
JONES, J. A., Gijon, Asturias, Spain.
JONES, JACOB CARLOS, Bellambi, New South Wales.
JONES, LLOYD, Plasisa, Rhosymedre, Ruabon, North Wales.

KANDA, REIJI, Hokkaido-Kozankabushikikaisha, Otaru, Hokkaido, Japan.
KAUFMAN, CHARLES, St. George's Terrace, Perth, Western Australia.
KAY, ROBERT, South Tanfield. Stanley, R.S.O., Co. Durham.
KAYLL, A. C., Gosforth, Newcastle-upon-Tyne.
KAYSER, H. W. FERD., The Mount Bischoff Tin Mining Co., Waratah, Tasmania.
KEIRS, JOHN, Drongan Castle Colliery, Drongan, Ayr, N.B.
KELL, G. J., Beech Grove, Locke Park, Barnsley.
KELLET, M. H., South Moor, Chester-le-Street.
KELLETT, WILLIAM, Portland Bank, Southport.
KENDALL, J. D., Mansion House Chambers, Queen Victoria Street, London, E.C.
KENNEDY, HENRY, Arniston Colliery, Gorebridge N.B.
KENNEDY, RANKIN, The Phœnix Dynamo Manufacturing Co., Hubert Street, Leeds Road, Bradford.
KENNEDY, WILLIAM, Gilburn Cottage, Shotts, N.B.
KENNEDY, WM., 509, West Sixth Street, Austin, Texas, U.S.A.
KENRICK, JOHN P., 8, St. James' Square, Manchester.
KERR, ARCHIBALD, Mayville, Cleland, Lanarkshire, N.B.
KESTEVEN, FRANK, Monckton Main Colliery, Barnsley.
KIDD, THOMAS, Jun., c/o Thomas Kidd, 104, Balham Park Road, Balham, London, S.W.
KILPATRICK, WM. M., Struther Colliery, Larkhall, N.B.
KING, HENRY, Daldowie Colliery, Broomhouse, Glasgow.
KIRKBY, J. W., Kirkland, Leven, Fife.
KIRKBY, RICHARD, Wellsgreen Colliery, Windygates, R.S.O., Fife.
KIRKUP, J. P., Burnhope, near Lanchester.
KIRKUP, PHILIP, Cornsay Colliery Office, Esh, near Durham.
KIRKWOOD, WILLIAM A., Clydeview, Larkhall, R.S.O., Lanarkshire.
KIRTON, HUGH, Kimblesworth Colliery, Chester-le-Street.
*KNIGHTON, H. A., Bagworth, Leicester. Transactions to go to Mr. West, Grocer, Eastwood, Notts.

KNOWLES, JOHN, The Pearson and Knowles Coal and Iron Company, Limited, Ince Hall Collieries, Wigan.
KNOWLES, ROBERT, Ednaston Lodge, Derby.
KNOX, JAMES, Rosebank Villa, Tranent, N.B.
KONDO, R., 7, Setomoncho, Nihonbashi, Tokio, Japan.
KWANG KWONG YUNG, c/o Chinese Engineering and Mining Company, Lin Si Colliery, Tientsin, North China.

LAIRD, ANDREW, 123, St. Vincent Street, Glasgow.
LAMB, GEORGE, Butterley Park, Butterley, Derby.
LAMB, R. O., West Denton, Newcastle-upon-Tyne.
LAMBERT, JAMES, The Hulton Colliery Company, Limited, Bolton.
LANCASTER, JOHN, Ashlawn, Rugby.
LANCASTER, JOHN, Heathfield, Lesmahagow, R.S.O., Lanarkshire.
LANDALE, A., Comely Park Place, Dunfermline.
LANDERO, CARLOS F. DE, c/o Real del Monte Company, P.O. Box 1, Pachuca, Mexico.
LANDLESS, JOHN, Bank Hall Colliery, Burnley.
LAPORTE, H., 57, Rue de la Concorde, Brussels.
LARMOUTH, WILLIAM, Harecastle and Woodshutts Colliery, Stoke-upon-Trent.
LATHAM, CHARLES, University College, Nottingham.
LAURIE, JOHN, Green Street, Bothwell, N.B.
LAVERICK, JAS., South Kirkby Colliery, near Wakefield.
LAVERICK, J. H. W., Pye Hill House, near Alfreton.
LAVERICK, JOHN WALES, Tow Law Colliery Office, Tow Law, R.S.O., Co. Durham.
LAVERICK, ROBT., West Rainton, Fence Houses.
LAWLEY, J., Cradley Road, Cradley Heath, Staffordshire.
LAWRENCE, H., Grange Iron Works, Durham.
LAWRENCE, H. L., c/o Dr. Magin, P.O. Box 733, Johannesburg, Transvaal.
LAWS, W. G., Town Hall, Newcastle-upon-Tyne.
LAWTON, GEORGE E., Shelton Collieries, Stoke-upon-Trent.
LEA, H., 38, Bennett's Hill, Birmingham.
LEACH, C. C., Seghill Colliery, Northumberland.
LEBOUR, G. A., Durham College of Science, Newcastle-upon-Tyne.
LECK, WILLIAM, H.M. Inspector of Mines, Cleator Moor, Cumberland.
LECKIE, R. G., Londonderry Iron Company, Limited, Londonderry, Nova Scotia.
LEE, JOHN F., Glapwell Colliery, Chesterfield.
LEE, J. W. R., 70, St. Helen's Gardens, North Kensington, London, W.
LEES, T. G., Clifton Colliery, Nottingham.
LEESON, HENRY, Cresswell Colliery, near Mansfield.
LEWIS, HENRY W., 154, West Regent Street, Glasgow.
LEWIS, GEORGE, Albert Street, Derby.
LEWIS, G. ALFRED, Albert Street, Derby,
LEWIS, HENRY, Annesley Colliery, Nottingham.
LEWIS, H. R., 7, Drapers' Gardens, London, E.C.
LEWIS, Sir WILLIAM THOMAS, Mardy, Aberdare.
LIDDELL, J. M., 3, Victoria Villas, Newcastle-upon-Tyne.
LINDAY, GEORGE, Blackett Colliery, Haltwhistle.
LINDAY, JAMES, Park Street Villas, Bridgend, Glamorganshire.
LINDLEY, EDWARD, Eastwood, Nottingham.

LINDOP, A. B., Blackball, *via* Greymouth, New Zealand.
LINDOP, J., Lime Tree House, Bloxwich, Walsall.
LINSLEY, R., Cramlington Colliery, Northumberland.
LISHMAN, R. R., South Hill House, Timsbury, near Bath.
LISHMAN, T., Hetton Colliery, Hetton-le-Hole, R.S.O.
LISHMAN, WM., Thornhill Park, Sunderland.
LISHMAN, WM., Holly House, Witton-le-Wear.
LISHMAN, W. E., South Hetton Colliery, *via* Sunderland.
LISLE, J., The Ottos Kopje Diamond Mines, Limited, Ottos Kopje Chambers, P.O. Box 381, Kimberley, South Africa.
LITTLE, GILBERT, Transport Appliance Works, Smethwick, Birmingham.
LIVEING, E. H., 52, Queen Anne Street, Cavendish Square, London, W.
LIVERSEDGE, W. G., 13, Broad Street, Sheffield.
LIVESEY, C., Bradford Colliery, near Manchester.
LIVESEY, T., Bradford Colliery, near Manchester.
LIVINGSTONE, ARCHIBALD, Shieldhill Colliery, Falkirk, N.B.
LLEWELLIN, DAVID MORGAN, Glanwern Offices, Pontypool.
LLEWELYN, F. W., Alsager, Cheshire.
LLOYD, G. HAMILTON, 7, St. Mildred's Court, Poultry, London, E C.
LOCHHEAD, JOHN A., Melita Cottage, Denny, N.B.
LOCKETT, JAMES, Avenue Villas, Kidsgrove, Stoke-upon-Trent.
LOGAN, WILLIAM, Langley Park Colliery, Durham.
LONGBOTHAM, J., Barrow Collieries, Barnsley, Yorkshire.
LONGBOTHAM, R. H., Ings Foundry, Wakefield.
LONGDEN, J. A., Stanton-by-Dale, Nottingham.
LONGRIDGE, J., Coxlodge Colliery, Newcastle-upon-Tyne.
LOUIS, D. A., 77, Shirland Gardens, London, W.
LOUIS, H., 11, Summerhill Terrace, Newcastle-upon-Tyne.
LOVE, ISAAC, Shotts Iron Works, Shotts, R.S.O., Lanarkshire.
LOVELY, W. H. C., Coolgardie, Western Australia.
LOWDEN, T., Hamsteels, near Durham.
LOWRANCE, T. B., Pitt Street, Barnsley.
LUCAS, ROBERT, Roseberry Villa, Alsager, Cheshire.
LUCAS, SAMUEL, Dronfield Foundry, Dronfield, Sheffield.
LUPTON, Prof. A., 6, De Grey Road, Leeds.
LYMN, A., Fir Tree Villa, Lower Ince Wigan.
*LYNAM, H. M., Shelton Collieries, Stoke-upon-Trent.
LYON, J., Walsall Wood, Walsall.

MACALPINE, G. W., Altham and Great Harwood Collieries, Accrington.
MACARTHUR, J. S., 108A, Hope Street, Glasgow.
MCBRIDE, JOHN, Merryton Colliery, Hamilton, N.B.
MCCALLUM, JOHN A., Jun., 5, Broomhill Terrace, N. Partick, Glasgow.
MCCARTHY, E. T., c/o Colonel Pigott, Archer Lodge, Charles Road, St. Leonards-on-Sea.
MCCONNELL, JAMES I., Burnfoot, Sanquhar, R.S.O., Dumfriesshire.
MCCREATH, GEORGE W., 208, St. Vincent, Glasgow.
MCCREATH, JAMES, 208, St. Vincent Street, Glasgow.
MCCULLOCH, DAVID, Vulcan Works, Kilmarnock, N.B.
MCCULLOCH, WILLIAM, Linkieburn House, Muirkirk, R.S.O., Ayrshire.
MCDONALD, JOHN, Jun., Parkhead Cottage, Polmont Station, Stirlingshire.

MACDONALD, SYMINGTON, The Great Kanawha Colliery Company, Limited, Mount Carbon, West Virginia, U.S.A.
McFARLANE, NIGEL, Kirkton, High Blantyre, Glasgow.
McGEACHIE, DUNCAN, Waratah Colliery, Charlestown, Newcastle, New South Wales.
McGOWAN, JOHN, Harecastle and Woodshutts Collieries, Stoke-upon-Trent.
McGOWAN, JOHN, Jun., Harecastle and Woodshutts Collieries, Stoke-upon-Trent.
MACHEN, WILLIAM, Church Street, Mortomley, Sheffield.
MACKAY, ANDREW, Grangemouth Coal Company, Grangemouth, N.B.
MACKAY, JAMES, Avonview Cottage, Avonbridge, Stirlingshire.
MACKAY, MUNGO, Newbattle Collieries, Dalkeith, N.B.
MACKINTOSH, JAMES, c/o T. & R. B. Ranken, 68, Queen Street, Edinburgh.
McLAREN, B., Jun., Portland House, Kirkby in Ashfield, Nottingham.
McLAREN, ROBERT, Bonny, Uddingston, Glasgow.
McLAREN, WILLIAM, Duntroon, Tollcross, Glasgow.
McLAUCHLAN, J. D., 19, St. Ninian's Terrace, Morningside Drive, Edinburgh.
McMILLAN, JAMES, Jun., Langloan, Coatbridge, N.B.
McMILLAN, JOHN, Elphingstone, Tranent, N.B.
McMURTRIE, G. E. J., Foxes Bridge Colliery, Cinderford, Gloucestershire.
McMURTRIE, J., Radstock Colliery, Bath.
McNAB, JOHN, Broomhall, Menstrie, R.S.O., Clackmannanshire.
McNAUGHTON, JAMES, 52, St. Enoch Square, Glasgow.
McPHAIL, JAMES, North Motherwell Colliery, Motherwell, N.B.
McPHEE, RICHARD, Bothwell Castle Colliery, Bothwell, Glasgow.
McVIE, JAMES, Cadzow Colliery, Hamilton, N.B.
MADDISON, THOS. R., Dirtcar House, near Wakefield.
MADDISON, W. H. F., The Lindens, Darlington.
MADDOCK, JAMES, Audley and Bunkers Hill Collieries, Stoke-upon-Trent.
MAKEPEACE, H. R., H.M. Inspector of Mines, Newcastle, Staffordshire.
MALCOLM, JAMES, Arniston Colliery, Gorebridge, N.B.
MALING, C. T., Ellison Place, Newcastle-upon-Tyne.
MALTBY, H. E., Lidgett Colliery, Tankersley, Barnsley.
MAMMATT, J. E., 1, Albion Place, Leeds.
MANN, ENOCH, Blakeley House, Dilhorne, Stoke-upon-Trent.
MARKHAM, C. P., Broad Oaks Iron Works, Chesterfield.
MARKHAM, G. E., Coundon, Bishop Auckland.
MARKS, HERBERT T., 27, Wallace Road, Canonbury, London, N.
MARLEY, J. W., Thornfield, Darlington.
MARRIOTT, JOSEPH, Jun., Acres, Pilsley, Chesterfield.
MARSH, P. N., Cliffe, Tamworth.
MARSH, T. G., 206, Wolverhampton Street, Dudley, Worcestershire.
MARSHALL, JOHN, Sea More House, Stevenston, Ayrshire.
MARSHALL, J. L., Monk Bretton Colliery, Barnsley.
MARSHALL, W., Liversedge Colliery, Liversedge, *via* Normanton.
MARSHALL, WILLIAM, Daldowie Colliery, Broomhouse, N.B.
MARSHALL, W. B., Richmond Hill, Edgbaston, Birmingham.
MARTEN, E. B., Pednore, near Stourbridge.
MARTIN, C. W., Newbottle Colliery Offices, Fence Houses.
MARTIN, GILSON, Edensor, Bakewell.
MARTIN, RALPH, Cardigan Stone Co., Limited, Llandyssil, South Wales
MARTIN, ROBERT, Niddrie Collieries, Portobello, N.B.

MARTIN, R. F., Mountsorrel, Loughborough.
MARTIN, TOM PATTINSON, Mealsgate, Carlisle.
MASON, F. H., Queen Building, Hollis Street, Halifax, Nova Scotia.
MATHIESON, ALEXANDER, Hetton Colliery, Carrington, near Newcastle, New South Wales.
MATTHEWS, D. H. F., Highfield, Kilnorey Park, Chester.
MATTHEWS, J., Messrs. R. and W. Hawthorn, Newcastle-upon-Tyne.
MATTHEWS, R. F., Harehope Hall, Alnwick.
MAVOR, SAMUEL, 3, Elmbank Crescent, Glasgow.
MAWSON, R. BRYHAM, Brick House, Westleigh, near Manchester.
MAY, GEORGE, The Harton Collieries, South Shields.
MAY, T. H., Dronfield, Sheffield.
MAYDEW, BENJ., St. John's House, Annesley Woodhouse, Nottingham.
MAYES, G. R., Wynnstay Collieries Limited, Ruabon, North Wales.
MEACHEM, F. G., Hillside Cottage, Hamstead Hill, Handsworth, Birmingham.
MEACHEM, ISAAC, Jun., Perry Park House, Old Hill, Staffordshire.
MEIKLE, HUGH, The Wemyss Coal Co., Limited, West Wemyss, Fife.
MEIN, JAMES, South Normanton Colliery, Alfreton.
MELDRUM, J. J., Atlantic Works, City Road, Manchester.
MELLING, WM., South Leicestershire Colliery, Coalville, Leicestershire.
MELLORS, JAMES, H.M. Inspector of Mines, Outwood, Wakefield.
MELLY, E. F., Griff Colliery, Nuneaton.
MENZIES, JOHN, Auchinraith Colliery, Blantyre, Glasgow.
MERIVALE, J. H., Togston Hall, Acklington, Northumberland.
MERIVALE, W., General Manager, Barbados Railway, Barbados, W.I.
MERRITT, W. HAMILTON, 485, Huron Street, Toronto, Ontario, Canada.
METCALF, A. T., The Cloisters, Maritzburg, South Africa.
MEYER, G. A., Shamrock Collieries, Westphalia.
MEYSEY-THOMPSON, A. H., Sun Foundry, Leeds.
MIDDLETON, FRANCIS ED., Lofthouse, Wakefield.
MIDDLETON, GEORGE, 186, Saracen Street, Possil Park, Glasgow.
MIDDLETON, ROBERT, Sheep Scar Foundry, Leeds.
MILLAR, ROBERT, Balgray Cottage, Maryhill, Glasgow.
MILLER, JAMES, 2, Ailsa Terrace, Hillhead, Glasgow.
MILLER, JOHN D., Rosehall Colliery, Coatbridge, N.B.
MILLER, J. P. K., H. C. Frick Coke Co., Scottdale, Pennsylvania.
MILLER, WILLIAM, Equitable Coal Company, Barrakur, E.I. Railway, Bengal, India.
MILLER, W. M., 12, St. Andrew Square, Edinburgh.
MILLIGAN, PETER, Milnwood Colliery, Bellshill, Lanarkshire.
MILLS, M. H., Mansfield Woodhouse, Mansfield.
MILNE, Prof. JOHN, Shide Hill House, Shide, Newport, Isle of Wight.
MITCHELL, CLAYTON E. J., Howden Lodge, Clarendon Road, Southsea.
MITCHELL, GEORGE A., 5, West Regent Street, Glasgow.
MITCHELL, JOHN, Heathercliffe Lodge, Penistone, Sheffield.
MITCHELL, JOHN, Delta House, Inveresk, Musselburgh, N.B.
MITCHELL, T. W. H., Eldon Street, Barnsley.
MITCHESON, G. A., Market Place, Longton, Staffordshire.
MITCHINSON, R., Pontop Colliery, Annfield Plain, R.S.O., Co. Durham.
MITTON, A. DURY, Oakhurst, Eccles, near Manchester.
MOLSON, C. A., Elkhorn Mining Co., Limited, Elkhorn, Jefferson County, Montana, U.S.A.

MONKHOUSE, JOS., Gilcrux, Carlisle.
MOODIE, THOMAS, Earnock Colliery, Hamilton, N.B.
MOORE, R. T., 156, St. Vincent Street, Glasgow.
MOORE, R. W., Somerset House, Whitehaven.
MOORE, THOMAS, Shipley Colliery, Derby.
MOORE, WILLIAM, Loftus Mines, Loftus-in-Cleveland, R.S.O.
MOREING, C. A., Broad Street House, Old Broad Street, London, E.C.
MORGAN, DAN., Stratton-on-the-Fosse.
MORGAN, C. R., Hurst Lodge, Alfreton.
MORISON, JOHN, Cramlington House, Northumberland.
MORRIS, W., Waldridge Colliery, Chester-le-Street.
MORTON, H. J., 2, Westbourne Villas, Scarborough.
MORTON, JAMES, Manor Park, Blairhill, Coatbridge, N.B.
MORTON, JAMES, Glen Villa, Charlestown, Fife.
MORTON, JOHN, Bredisholm Colliery, Baillieston, Glasgow.
MORTON, JOHN, 8, Garden Street, Galston, R.S.O., Ayrshire.
MORTON, R. M., Ansonhill House, Crossgates, R.S.O., Fifeshire.
MORTON, W. S., Baton Colliery, Shotts, N.B.
MOSES, WILLIAM, De Beers Consolidated Mines, Limited, Kimberley, South Africa.
MOTTRAM, A. H., Bourtreehill Colliery, Dreghorn, R.S.O. Ayrshire.
MOTTRAM, T. H., 6, Kelvinside Gardens, Glasgow.
MOUNTAIN, WILLIAM C., Forth Banks, Newcastle-upon-Tyne.
MOWAT, DAVID M., Summerlee Iron Works, Coatbridge, N.B.
MUIR, J. HARVEY, 140, Bath Street, Glasgow.
MUIR, ROBERT, Bog Colliery, Hamilton, N.B.
MUIR, ROBERT A., Lindsay Place, Blairadam, Kinross-shire.
MUIR, WALTER, North Broomage, Larbert, N.B.
MUIR, W. W., Halbeath Colliery, Dunfermline, N.B.
MULHOLLAND, M. L.
MUNDLE, ARTHUR, Bank Chambers, 24, Grainger Street West, Newcastle-upon-Tyne.
MUNGALL, HENRY, Cowdenbeath Collieries, Cowdenbeath, R.S.O., N.B
MUNGALL, WALTER H., Transy, Dunfermline, N.B.
MUNRO, DONALD, Fairfield, Manchester.
MUNRO, JAMES, Quarter Collieries, Hamilton N.B.
MUNRO, NEIL, Gavell Cottage, Kilsyth, Glasgow.
MUNRO, R. D., 13, Dundas Street, Glasgow.
MURRAY, JAMES, Merryton Colliery, Hamilton, N.B.
MURRAY, JOHN, Raneegunge Coal Association, Limited, Giridih, India.
MURRAY, ROBERT, Benvue, Bo'ness, R.S.O., Linlithgowshire.
MURTON, CHAS. J., Delaval Benwell Colliery, Newcastle-upon-Tyne.
MUSCHAMP, PERCIVAL, Warren Grove, Sheffield Road, Barnsley.
MUSGRAVE, HENRY, Havercroft Main Colliery, Roystone, near Barnsley.
MYATT, JACOB, Newchapel, Tunstall, Staffordshire.

NAPIER, JAMES, Leven Bank, Cambuslang, Glasgow.
NASH, H. B., Clarke's Old Silkstone Colliery, Barnsley.
NASMYTH, A. H., Donibristle Colliery, Crossgates, R.S.O., Fifeshire.
NASMYTH, G. B., Dundonald, Cardenden, R.S.O., Fifeshire.
NASSE, RUDOLPH, Geheimer Oberbergrath, Dörnsbergstrasse, 6, Berlin, Germany.

NEILSON, GEORGE, Crossbasket, High Blantyre, Glasgow.
NESS, HENRY, Townhill, Dunfermline, N.B.
NEVIN, JOHN, Littlemoor House, Mirfield.
NEWBIGIN, H. T., 7, Lovaine Crescent, Newcastle-upon-Tyne.
NEWBOULD, T., Low Stubbin Colliery, Rawmarsh, Rotherham.
NEWTON, JAMES, Whitehaven Colliery, Whitehaven.
NEWTON, JOHN, Longport, Stoke-upon-Trent.
NICHOL, WM., De Beers Mine, Kimberley, South Africa.
NICHOLSON, J. COOK, Collingwood Street, Newcastle-upon-Tyne.
NICHOLSON, J. H., Cowpen Colliery Office, Blyth, Northumberland.
NICHOLSON, MARSHALL, Middleton Colliery, Leeds.
NIMMO, JAMES.
NIMMO, JAMES, 12, St. Giles Street, Edinburgh.
NISBET, ANDREW, Lochgelly Colliery, Lochgelly, R.S.O., Fifeshire.
NISBET, HENRY, Comely Bank, Leven, Fifeshire.
NISBET, JAMES, 208, St. Vincent Street, Glasgow.
NITCH, H. G., c/o G. H. Nitch, Standard Bank, Johannesburg, Transvaal.
NIVISON, JOHN, Dykehead Colliery, Larkhall, R.S.O., Lanarkshire.
NOBLE, THOMAS GEORGE, Sacriston Colliery, Durham.
NORTH, F. W., 18, St. Swithin's Lane, London, E.C.
NOWELL, WILLIAM, Haunchwood Colliery, Nuneaton.

OAKES, C. H., Newlands, Alfreton.
OATES, R. J. W., Manager, Government Central Provinces Collieries, Umaria, *via* Katni, C.P., India.
OFFER, STEPHEN, The Elms, Cheadle, Staffordshire.
OGILVIE, A. GRAEME, 8, Grove End Road, St. John's Wood, London.
OKE, F. R., 5, Coppenhall Terrace, Crewe.
OLDHAM, GEORGE, 25, Western Hill, Durham.
OLIVER, C. J., Spring Vale, Spital, Chesterfield.
OLIVER, SEPTIMUS, Tyne House, Tynemouth.
ORMISTON, A. R., 203, St. Vincent Street, Glasgow.
ORMISTON, JAMES, 203, St. Vincent Street, Glasgow.
ORNSBY, R. E., Seaton Delaval Colliery, Newcastle-upon-Tyne.
ORR, THOMAS, Bredisholm Colliery, Uddingston, Glasgow.
O'SHEA, L. T., Firth College, Sheffield.
OSWALD, R. P. W., H.M. Inspector of Mines, 28, Lismore Terrace, Carlisle.
OVEREND, JAMES, Mining Offices, Barnsley.
OWEN, JAMES L., 120, Colmore Row, Birmingham.

PACEY, J. WM., Burley Cottage, Apedale, Newcastle, Staffordshire.
PALMER, A. S., 3, Victoria Square, Newcastle-upon-Tyne.
PALMER, C. B., Wardley Hall, near Newcastle-upon-Tyne.
PALMER, Sir CHAS. MARK, Bart., M.P., Quay, Newcastle-upon-Tyne.
PALMER, HENRY, Medomsley, R.S.O., Co. Durham.
PAMELY, C., Wye Cliff House, Welsh Street, Chepstow.
PANTON, F. S., Silksworth Colliery, Sunderland.
PARK, ALEXANDER, Drumdow Cottage, Stair, Coylton, Ayrshire.
PARKER, JOSEPH, Montgomery Street, Larkhall, N.B.
PARKER, WILLIAM, Woodville Cottages, Armadale, Bathgate, N.B.
PARKIN, J., Fox Holes Colliery, Methley, near Leeds.

PARKIN, L. C., Joan Royd House, White Lee, Heckmondwike.
PARKINSON, F. B., Cruzille, Prestbury Road, Cheltenham.
PARRINGTON, M. W., Wearmouth Colliery, Sunderland.
PARRY, D. E., Norton Cannock Colliery, Bloxwich, Walsall.
PARRY, EVAN, Wharncliffe Woodmoor Colliery, Barnsley.
PARSONS, Hon. CHARLES ALGERNON, Holeyn Hall, Wylam-upon-Tyne.
PARSONS, C. E., Grand Hotel, Auckland, New Zealand.
PARTON, ARTHUR, Willenhall, Wolverhampton.
PASFIELD, T., 24, Wellington Road, Dudley, Worcestershire.
PATERSON, J. R., Coal Creek Proprietary Company, Finks Buildings, Melbourne, Australia.
PATERSON, PETER, Blackstone Mineral Works, Paisley, N.B.
PATERSON, Rev. T. M. B., Ardenclutha, Hamilton, N.B.
PAYTON, EDMUND, Yew Tree House, Morleston Street, Derby.
PEACOCK, W. F., Horsley Collieries, Tipton.
PEAKE, H. C., Walsall Wood Colliery, Walsall.
PEAKE, R. C., Cumberland House, Redbourn, Herts.
PEARCE, GILES OTIS, 708, Colorado Avenue, Colorado City, Colorado, U.S.A.
PEARSON, ALEXANDER, Parkhouse Colliery, Chesterton, Staffordshire.
PEARSON, ANDREW, Stonelaw Cottage, Rutherglen, Glasgow.
PEARSON, HUGH, Caldercruix, Airdrie, N.B.
PEARSON, JAMES, Brampton Manor, Chesterfield.
PEARSON, JOHNSON, The Red House, Whittington, Chesterfield.
PEASE, Sir J. W., Bart., M.P., Hutton Hall, Guisbrough, Yorkshire.
PEEL, ROBERT, New Brancepeth Colliery, Durham.
PEET, WM., 8, Park Terrace, Worsborough, Barnsley.
PEILE, WILLIAM, Croft Hill, Moresby, Whitehaven.
PENDLETON, W. B., Harris Road, Five Dock, near Sydney, New South Wales.
PENMAN, JAMES, Greystonelea Colliery, Shotts, R.S.O., Lanarkshire.
PENMAN, ROBERT, Strathclyde Street, Dalmarnock, Glasgow.
PERCY, C. M., King Street, Wigan. Transactions to the Librarian, Wigan Free Library, Wigan.
PERCY, W. R., Hamilton Lodge, Sherwood Rise, Nottingham.
PERNOLET, ARTHUR, 87, Rue Lafayette, Paris.
PETRIE, J. L., Winterdyne, Uddingston, near Glasgow.
PETTIGREW, ROBERT, Tinto View, Airdrie, N.B.
PHILLIPS, HERBERT, Box 70, Salisbury, Mashonaland.
PHILLIPS, W. G., Ansley Hall Colliery, Atherstone, Warwickshire.
PICKUP, P. W., The Quarry, Colwall, Malvern.
PIGGFORD, JONATHAN, Stanton Iron Works (Limited) Company's Collieries, near Mansfield.
PLATT, SAMUEL R., Oldham.
PLOWRIGHT, ROBERT, Brampton Iron Works, Chesterfield.
PLUMMER, JOHN, H.M. Inspector of Mines, Bishop Auckland.
POLLARD, JOHN, Central Chambers, King Street, Wakefield.
POOLE, HENRY, 68, Laurel Road, Fairfield, Liverpool.
POOLE, P. G., P.O. Box 20, Klerksdorp, South Africa.
POTTER, A. M., Aydon Grange, Corbridge-upon-Tyne.
POTTER, C. J., Heaton Hall, Newcastle-upon-Tyne.
POTTS, SAMUEL, 11, Bothwell Street, Hamilton, N.B.
POWER, F. DANVERS, 68½ Pitt Street, Sydney, New South Wales.

PRENTICE, JAMES, Stanrigg Collieries, Airdrie, N.B.
PRENTICE, THOMAS, Brisdanehill, West Calder, N.B.
PRENTICE, WILLIAM P., Dalmeny Works, Dalmeny, R.S.O., Midlothian.
PREST, J. J., Shelton Iron, Steel and Coal Co., Limited, Stoke-upon-Trent.
PRESTWICH, J., Irwell Park, Eccles, Manchester.
PRICE, J. H., Rowley Regis, Dudley, Worcestershire.
PRICE, S. R., c/o Messrs. Forster Brown and Rees, 12, Victoria Street, Westminster, London, S.W.
PRICE, S. WARREN, 25, Lochaber Street, Cardiff.
PRICE-WILLIAMS, R., Victoria Mansions, 32, Victoria Street, London, S.W.
PRIESTLEY, J. G., Glass Houghton Colliery, Castleford.
PRINGLE, EDWARD, Choppington Colliery, Northumberland.
PRIOR, EDWARD G., Victoria, British Columbia. Transactions, etc., to be sent to Wm. McGregor, Nanaimo, British Columbia.
PRITCHETT, C. W., Jun., Apartado 196, San Luis Potosi, Mexico.
PROUT, JAMES, 16, Claremont Road, Redruth, Cornwall.
PROVAN, JOHN, Balgonie Colliery, Thornton, Fife.
PURCELL, S., Monck Hill, Pontefract.

QUIRK, J. S., St. Helens Lead Smelting Works, St. Helens, Lancashire.

RÄBER, ANTON, c/o Messrs. Heenan and Froude, Birmingham.
RABY, G. E., Lota, Chili.
RAMSAY, JAMES.
RAMSAY, J. A., Sherburn and Littletown Collieries, near Durham.
RAMSAY, W., Tursdale, Co. Durham.
RAMSAY, WILLIAM, Enterkine Lodge, Annbank, Ayr, N.B.
RANCE, C. E. DE, 55, Stoke Road, Shelton, Stoke-upon-Trent.
RANDOLPH, BEVERLEY S., Frostburg, Maryland, U.S.A.
RANDOLPH, JOHN C. F., Mills Buildings, 35, Wall Street and 15, Broad Street, New York, U.S.A.
RANGELEY, W. H., Stafford House, Chesterfield.
RANKIN, JOHN, Jun., Harwarden, Bothwell, N.B.
RANKINE, DAVID, 238, West George Street, Glasgow.
RASPASS, J. C. T., Elm Grove, Madeley, Salop.
RAVENSHAW, HENRY W., 110, Cannon Street, London, E.C.
READER, G. F., Chasetown, Walsall.
REDMAYNE, R. A. S., Seaton Delaval Colliery, Newcastle-upon-Tyne.
REDWOOD, BOVERTON, Glenwathen, Church End, Finchley, London, N.
REID, ALEXANDER, The Kent Coalfields Syndicate, Limited, Dover.
*REID, ANDREW, Printing Court Buildings, Newcastle-upon-Tyne.
REID, ARTHUR H., P.O. Box 746, Johannesburg, Transvaal.
REID, FRANCIS, 13, Railway Arches, Westgate Road, Newcastle-upon-Tyne.
REID, P. S.
RENSHAW, W. R., Phœnix Foundry and Boiler Works, Stoke-upon-Trent.
RENWICK, T. C., Manor House, Lumley Park, Fence Houses.
RHODES, B. A., Highfield, Kirkburton, Huddersfield.
RHODES, C. E., Aldwarke Main and Car House Collieries, Rotherham.
RHODES, F. B. F., Superintendent of the National Smelting and Refining Company, South Chicago, Illinois, U.S.A.
RHODES, JEREMIAH, Shirland Colliery, Alfreton.

RICH, WM., Minas de Rio Tinto, Provincia de Huelva, Spain.
RICHARDSON, A. M., 44, Victoria Road, Leeds.
RICHARDSON, H., Backworth Colliery, Newcastle-upon-Tyne.
RICHARDSON, R., Blaydon Main Colliery, Blaydon-upon-Tyne.
RICHARDSON, RALPH, Whitburn Colliery, South Shields.
RIDDELL, WILLIAM.
*RIDLEY, G., 16, Dean Street, Newcastle-upon-Tyne.
RIDLEY, N. B., 58, Collingwood Street, Newcastle-upon-Tyne.
RIDSDALE, LANGFORD, Ingleside, Burton Road, Tamworth.
RIDYARD, J., Hilton Bank, Little Hulton, Bolton-le-Moors.
RIGBY, FRANK, Alsager, Stoke-upon-Trent.
RITSON, J., Jun., The Green, Dodworth, Barnsley.
RITSON, U. A., 15, Queen Street, Newcastle-upon-Tyne.
RITSON, W. A., Crumpsall, Manchester.
ROBERTS, JAMES, Western Colliery, Maryhill, Glasgow.
ROBERTS, JAMES, Jun., Perranporth, R.S.O., Cornwall.
ROBERTS, J. H., Woodroyd, Honley, Huddersfield.
ROBERTS, ROBERT, Oakley Slate Quarries Company, Limited, Blaenau Festiniog, North Wales.
ROBERTS, SAMUEL, Queen's Tower, Sheffield.
ROBERTSON, D. A. W., Metropolitan Coal Co., Helensburgh, Illawarra Line, New South Wales.
ROBERTSON, Dr. J. R. M., Linton, Pitt Street, Wilson's Point, Sydney, New South Wales.
ROBERTSON, RICHARD, Rosebank Colliery, Dunfermline, N.B.
ROBERTSON, W., 123, St. Vincent Street, Glasgow.
ROBERTSON, W. M., 70, Great Clyde Street, Glasgow.
ROBIN, GEORGE, Transvaal Gold Exploration and Land Company, Pilgrim's Rest, Transvaal.
ROBINS, S. M., Superintendent, The New Vancouver Coal Mining and Land Company, Limited, Nanaimo, British Columbia.
ROBINSON, C., P.O. Box 45, Lydenburg, S.A.R.
ROBINSON, GREENWOOD, Woolley Moor Colliery Company, Limited, Crigglestone, Wakefield.
ROBINSON, G. C., Brereton and Hayes Colliery, Rugeley, Staffordshire.
ROBINSON, J. B., Hedley Hill Colliery, Waterhouses.
ROBINSON, JOHN THOMAS, South Medomsley Colliery, Dipton, R.S.O.
ROBINSON, R., Howlish Hall, near Bishop Auckland.
ROBINSON, R. H., Heatherdene, Heanor, Nottingham.
ROBINSON, THOMAS, Alsager House, Dresden, Stoke-upon-Trent.
ROBINSON, W. G., Ainley Grange, Elland.
ROBSON, J. S., Butterknowle Colliery, *via* Darlington.
ROBSON, T. O., Chowdene Cottage, Low Fell, Gateshead-upon-Tyne.
ROCHESTER, W., River View, Blaydon-upon-Tyne.
ROGERS, D., Dudley Road, Tipton, Staffordshire.
ROLKER, C. M., Manager, Mining and Financial Trust Syndicate, Limited, 6, Draper's Gardens, London, E.C.
ROME, J. E., 6, Roseburn Place, Edinburgh.
RONALDSON, J. H., Mount Kembla, Wollongong, New South Wales.
RONALDSON, J. M., H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
ROSCAMP, J., Shilbottle Colliery, Lesbury, R.S.O., Northumberland.

ROSCOE, GEORGE, Peel Hall Collieries, Little Hulton, Bolton, Lancashire.
Ross, HUGH, Croxdale Colliery Office, Durham.
Ross, JOHN, Dailly, Ayrshire.
Ross, MICHAEL, Westburn Colliery, Newton, N.B.
ROTHWELL, R. P., 253, Broadway (P.O. Box 1833), New York, U.S.A.
ROUTLEDGE, JOS., Greenbank, Chester-le-Street.
ROUTLEDGE, J. L., Waterloo Main Colliery, near Leeds.
ROUTLEDGE, R., Garforth Colliery, Leeds.
ROUTLEDGE, W. H., The Rhyd, Tredegar, Monmouthshire
ROWAN, DONALD, Harthill, Whitburn, Linlithgowshire.
ROWAN, FRED. J., 121, West Regent Street, Glasgow.
ROWAN, HENRY, Hill of Beath Colliery, Crossgates, R.S.O., Fifeshire.
ROWAN, JAMES, Inspector of Collieries, Wollongong, New South Wales.
ROWAN, WALTER, Dundee Natal Coal Company, Natal, South Africa.
ROWAND, ROBERT, Wakefield.
ROWLEY, WALTER, 20, Park Row, Leeds.
ROY, HENRY, Redding Colliery, Polmont Station, Stirlingshire.
ROY, JOHN, Fireclay Works, Castlecary Station, Glasgow.
ROY, ROBERT P., Mount Carron, Larbert, N.B.
ROY, WILLIAM, Hopefield, Airdrie, N.B.
ROXBURGH, ALEXANDER, Alloa Colliery, Alloa, N.B.
RUSSELL, ANDREW, Urie Place, Calder Street, Motherwell, N.B.
RUSSELL, GEORGE, Summerlee Iron Works, Coatbridge, N.B.
RUSSELL, JAMES, Ukalunda, *via* Bowen, Queensland.
RUSSELL, ROBT., Coltness Iron Works, Newmains, N.B.
RUSSELL, W. S., Stand Cottage, by Airdrie, N.B.
RUTHERFORD, W., South Derwent Colliery, Annfield Plain, Lintz Green.
RUTHVEN, The Hon. WALTER, Barncluith, Hamilton, N.B.

SAINT, G., Vauxhall House, Ruabon, North Wales.
SAISE, WALTER, Giridih, E.I.R., Bengal, India.
SALMOND, JAMES, Barncluith Colliery, Hamilton, N.B.
SALMOND, WALTER, Pinxton Collieries, Alfreton.
SAM, T. B. F., c/o Messrs. F. and A. Swanzy, Cape Coast Castle, West Africa.
*SAM, W. E., Jun., c/o Messrs. F. and A. Swanzy, Cape Coast Castle, West Africa.
SAMBORNE, JOHN STUKELY PALMER, Timsbury House, Bath.
SAMPSON, JOHN, Wellsgreen Cottages, Windygates, Fife.
SANER, C. T., P.O. Box 1831, Johannesburg, Transvaal.
SANKEY, W. H., Morley Hall, Derby.
SAWYER, A. R., 40, Brompton Square, London, S.W., and P.O. Box 2233, Johannesburg, Transvaal.
SCARTH, W. T., Raby Castle, Staindrop, Darlington.
SCHRAM, RICHARD, 17A, Great George Street, Westminster, London, S.W.
SCHROLLER, WM., 38, Claypath, Durham.
SCOTT, C. F., Grove Cottage, Leadgate, Co. Durham.
SCOTT, ELGIN, Ropienka Oil Wells, Ropienka, Galicia, Austria.
SCOTT, ERNEST, Close Works, Newcastle-upon-Tyne.
SCOTT, F., Reddish, Stockport, Manchester.
SCOTT, F. BOWES, Coolgardie Chambers, Coolgardie, Western Australia.
SCOTT, F. W., Atlas Wire Rope Works, Reddish, Stockport.
SCOTT, JOSEPH, Ngahire, *via* Greymouth, New Zealand.

SCOTT, J. S., Trimdon Hall, Trimdon Grange, R.S.O., Co. Durham.
SCOULAR, G., St. Bees, Cumberland.
SCRIVENER, EDWARD E., The Cedars, Brampton, Newcastle, Staffordshire.
SEAMON, W. H., New School of Mines, Socorro, New Mexico.
SECCOMBE, ALFRED F., Albaston, Gunnislake, Cornwall.
SEELY, SIR CHARLES, BART., Sherwood Lodge, Arnold, Notts.
*SELBY, ATHERTON, Leigh, near Manchester. Transactions, etc., to be addressed to John B. Selby, Leigh, near Manchester.
SELKIRK, J. G., Dalton-in-Furness.
SELLERS, ERNEST, Metropolitan Colliery, Helensburgh, New South Wales.
SENIOR, A., Birk House, Barnsley.
SETTLE, JOEL, The Hill, Alsager, Stoke-upon-Trent.
SETTLE, MILES, Darcy Lever Collieries, near Bolton.
SETTLE, W., Darcy Lever Colliery, Bolton.
SEYMOUR, G. E., 5, Rutland Villas, West Park, Chesterfield.
SEYMOUR, L. IRVING, P.O. Box 149, Johannesburg, South African Republic.
SHARPE, GEORGE, Shotts Iron Works, Shotts, R.S.O., Lanarkshire.
SHAW, F. G., c/o Messrs. Bainbridge, Seymour, and Co., 13, St. Helen's Place, London, E.C.
SHAW, G., Wath Main Colliery, Rotherham.
SHAW, JOHN, Welburn Hall, Kirby Moorside, R.S.O., Yorkshire.
SHAW, JOHN, Isle Cottage, Muirkirk, N.B.
SHAW, J. LESLIE, Somerset House, Whitehaven.
SHEAFER, A. W., Pottsville, Pennsylvania, U.S.A.
SHEARD, R., Caldervale Boiler Works, Wakefield.
SHEARER, JAMES A., Earnock Colliery, Hamilton, N.B.
SHIEL, JOHN, Framwellgate Colliery, Co. Durham.
SHORE, THOMAS, Manager, Shag Point Colliery, Otago, New Zealand.
SHORE, WM. MARTIN, Kaitangata Railway and Coal Co.'s Collieries, Otago, New Zealand.
SHORT, W., Lambton Colliery, Newcastle, New South Wales.
SHOTTON, JOHN, Ottoman Railway Company, Smyrna, Asia Minor.
SHUTE, C. A., High Terrace, Darlington.
SIBOLD, C. W., Public Works Department, Soane Circle, Arrah, Bengal, India.
SIDEBOTHAM, J. N., 1, Princess Street, Albert Square, Manchester.
SILVESTER, FRED., Newcastle, Staffordshire.
SIMON, FRANK, P.O. Box 2986, Johannesburg, Z.A.R.
SIMPKIN, ARTHUR, South Kirkby, near Wakefield.
SIMPKIN, J. W., Midsomer Norton, Bath.
SIMPSON, C. L., Engine Works, Grosvenor Road, Pimlico, London.
SIMPSON, DUNDAS, Ellismuir Collieries, Baillieston, Glasgow.
SIMPSON, F. L. G., Mohpani Coal Mines, Gadawarra, C.P., India.
SIMPSON, F. R., Hedgefield House, Blaydon-upon-Tyne.
SIMPSON, J., Heworth Colliery, Felling, R.S.O., Co. Durham.
SIMPSON, J. B., Bradley Hall, Wylam-upon-Tyne.
SIMPSON, ROBERT, 98, P.O., Buluwayo, Matabeleland, South Africa.
SKINNER, SAMUEL, Throapham Manor, Rotherham.
SLACK, J., Rockingham Colliery, Barnsley.
SLADDEN, HARRY, Box 1666, Johannesburg, Transvaal.
SLINN, T., Plashetts Colliery, Falstone, Northumberland.
SMAILES, JNO., Hebburn Colliery, Newcastle-upon-Tyne.

SMALLMAN, REUBEN, Camp Hill Grange, Nuneaton.
SMART, A., De Beers Mine, Kimberley, South Africa.
SMELLIE, ARCHIBALD, Bank Colliery, New Cumnock, N.B.
SMITH, C. SEBASTIAN, Shipley Collieries, Derby.
SMITH, DAVID, Dalmellington Iron Works, Ayr, N.B.
SMITH, DAVID, 10, Ferniegair, Hamilton, N.B.
SMITH, DAVID L., Knockhill, Beith, N.B.
SMITH, EUSTACE, Newcastle-upon-Tyne.
SMITH, G. E., 58, Mapperley Road, Nottingham.
SMITH, GEORGE W., Port Elizabeth, South Africa.
SMITH, H., North Side, Queen's Dock, Hull.
SMITH, JAMES, Hallhill Colliery, Baillieston, Glasgow.
SMITH, JOHN, Bickershaw Collieries, Leigh, Lancashire.
SMITH, J. B., Newstead Colliery, Nottingham.
SMITH, R. CLIFFORD, Ashford Hall, Bakewell.
SMITH, SYDNEY A., 1, Princes Street, Albert Square, Manchester.
SMITH, WILLIAM, Dunaskin, Ayr, N.B.
SNEDDON, JAMES B., Oakbank Colliery, Mid-Calder, N.B.
SNELL, ALBION T., South View, Brondesbury Road, London, N.W.
SNOW, CHARLES, Hickleton Main Colliery Company, Limited, Thurnscoe, Rotherham.
SOAR, ED., Kiveton Park Colliery, Sheffield.
SOAR, H. G., Frystone Collieries, Castleford.
SOAR, M., Warren, Chapeltown, Sheffield.
SOMERVILLE, W. W., 10, Ferniegair, Hamilton, N.B.
SOPWITH, ARTHUR, Cannock Chase Collieries, near Walsall.
SOUTHALL, A. B., Monckton Main Colliery, Barnsley.
SOUTHALL, WILLIAM, Park Hall Colliery, Cheadle, Staffordshire.
SOUTHERN, E. O., Ashington Colliery, near Morpeth.
SOUTHERN, R., Burleigh House, The Parade, Tredegarville, Cardiff.
SOUTHERN, T. A., 111, Rose Hill Street, Derby.
SOUTHWORTH, THOS., Hindley Green Collieries, near Wigan.
SPARGO, EDMUND, 3, Cable Street, Liverpool.
SPARKES, J. S., Highview House, Pucklechurch, Gloucestershire.
SPEIRS, ADAM, Newliston Mine, Kirkliston, R.S.O., Linlithgowshire.
SPENCE, FRANCIS JOSEPH, 94, South Terrace West, Adelaide, Australia.
SPENCE, R. F., Backworth, R.S.O., Northumberland.
SPENCER, E. D., Bakewell House, Clarendon Park Road, Leicester.
SPENCER, F. H., Bonanza Gold Mining Co., Box 149, Johannesburg, Transvaal
SPENCER, GEORGE, Stanley Lodge, West Hallam, Derby.
SPENCER, J., Globe Tube Works, Wednesbury.
SPENCER, JOHN, Westgate Road, Newcastle-upon-Tyne.
SPENCER, J. W., Newburn, near Newcastle-upon-Tyne.
SPENCER, RICHARD, Hanover Square, Leeds.
SPENCER, T., Ryton, Newcastle-upon-Tyne.
SPENCER, WILLIAM, Southfields, Leicester.
SPOONER, GEORGE, Cortonwood Colliery, Barnsley.
SPRUCE, SAMUEL, Beech House, Tamworth.
SQUIRE, J. B., 297, Clapham Road, London, S.W.
STAFFORD, THOMAS W., 1, Lea Road, Heaton Chapel, Stockport
STALEY, A. H., 21, Coton Road, Nuneaton.

STANDLEY, WILLIAM, Glenroy, Nuneaton.
STANLEY, REGINALD, Stanley's Engineering Company, Nuneaton.
STANSFELD, HAROLD SINCLAIR, High Hazels Colliery, Darnall, Sheffield.
STANTON, JOHN, 11 and 13, William Street, New York, U.S.A.
STATHAM, WILLIAM, Field House, Chesterton, Newcastle, Staffordshire.
STEAR, J., Strafford Colliery, Barnsley.
STEAVENSON, A. L., Durham.
STEAVENSON, C. H., Redheugh Colliery, Gateshead-upon-Tyne.
STEELE, RICHARD, Hanley, Staffordshire.
STEELE, WARDLE, Willington Colliery, Co. Durham.
STEPHENSON, G. R., Ben Braich, Tilehurst Road, Reading.
STEVENS, A. J., Uskside Iron Works, Newport, Monmouthshire.
STEVENS, JAMES, 9, Fenchurch Avenue, London, E.C.
STEVENSON, HENRY, Hillside, Pinxton, Alfreton.
STEVENSON, HUGH, 21, Clyde Place, Glasgow.
STEVENSON, THOMAS, Earnock Colliery, Hamilton, N.B.
STEVENSON, WILLIAM, Raebog Cottage, Airdrie, N.B.
STEWART, ALEXANDER, c/o Broken Hill Proprietary Company, Limited, Broken Hill, *via* Adelaide, New South Wales.
STEWART, W., Powells Tillery Steam Coal Co., Limited, Abertillery, Monmouthshire.
STOBART, F., Biddick Hall, Fence Houses.
STOBART, H. T., Wearmouth Colliery, Sunderland.
STOBART, W., Pepper Arden, Northallerton.
STOBART, W. R., Etherley Collieries, Co. Durham.
STOBBS, J. T., Walker Colliery, Walker-upon-Tyne.
STOIBER, EDWARD G., P.O. Box 129, Silverton, Colorado, U.S.A.
STOKER, ARTHUR P., Birtley, near Chester-le-Street.
STOKER, HENRY, 5, Argyll Mount, Mansfield.
STOKER, THOMAS E., 37, Whitehouse Lane, Ushaw Moor, Durham.
STOKES, JOHN, Tollcross Colliery, Tollcross, Glasgow.
STONES, GEORGE B., Dale View, Conisbro', Rotherham.
STOREY, THOS. E., Weston Coyney Hall, Longton, Staffordshire.
STRAIN, HUGH, Cleddans, Easterhouse, Baillieston, Glasgow.
STRAIN, JAMES M., 11, Hillend Gardens, Partickhill, Glasgow.
STRAKER, J. H., Howden Dene, Corbridge-upon-Tyne.
STREATFIELD, HUGH S., Ryhope, near Sunderland.
STREET, JOHN, High Street, Silverdale, Newcastle, Staffordshire
STRICK, JOHN, Bar Hill, Madeley, Staffordshire.
STRICK, R. J., Yniswern, Mumbles, Swansea.
STUART, DONALD M. D., Redland, Bristol.
STUBBS, THOMAS, Aldwarke Main Colliery, Rotherham.
SUTTON, WILLIAM, Kinsley, Hemsworth, Wakefield.
SWALLOW, J., Catchgate, Annfield Plain, R.S.O., Co. Durham.
SWALLOW, J. F., Mosboro' Hill House, Eckington, Sheffield.
SWALLOW, R. T., Simonside House, Simonside, South Shields.
SWAN, H. F., North Jesmond, Newcastle-upon-Tyne.
SWAN, J. G., Upsall Hall, near Middlesbrough.
SWANN, HUGH P., Gartcraig, Shettleston, N.B.
SYKES, FRANK K., Springwell Villa, Bishop Auckland.

TATE, HENRY, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.
TATE, SIMON, Trimdon Grange Colliery, Co. Durham.
TATTLEY, WILLIAM, Taupiri Extended Coal Mining Company, Limited, Huntly, Waikato, New Zealand.
TAYLOR, HUGH, East Holywell Office, Quayside, Newcastle-upon-Tyne.
TAYLOR, JOHN HY., Borough Surveyor, Barnsley.
TAYLOR, T., Quay, Newcastle-upon-Tyne.
TEALE, W. E., Swinton, near Manchester.
TEASDALE, T., Middridge, *via* Heighington, R.S.O.
TELFER, HENRY, Birkhill, Uddingston, Glasgow.
TELFORD, W. H., Hedley Hope Collieries, Tow Law, R.S.O., Co. Durham.
TEMPERLEY, JOSEPH, Harriston, Aspatria, Carlisle.
TERRIS, HENRY, Clackmannan Colliery, Clackmannan, Alloa, N.B.
THIRKELL, E. W., Oaks Colliery, Barnsley.
THOM, ARCHIBALD, Moresby Coal Company, Whitehaven.
THOM, JAMES R., Balbardie Colliery, Bathgate, N.B.
THOMAS, J. J., Newnham Cottage, Kendal.
THOMAS, R., Bloxwich, Walsall.
THOMAS, R. G., 47, Talbot Terrace, Rugeley.
THOMAS, W., Penelvan, Camborne, Cornwall.
THOMPSON, CHARLES LACY, Farlam Hall, Brampton Junction, Cumberland.
THOMPSON, F. W., 15, Wood Street, Bolton, Lancashire.
THOMPSON, JOHN G., Bamfurlong, Wigan.
THOMPSON, R., Jun., 19, The Crescent, Gateshead-upon-Tyne.
THOMPSON, THOMAS, Featherstone Main Collieries, Pontefract.
THOMPSON, WM., 58, New Broad Street, London, E.C.
THOMSON, ALEXANDER McD., Raith Colliery, Cowdenbeath, R.S.O., Fifeshire.
THOMSON, A. S., Brahmin Bararee, Jherriah P.O., Dist. Manbhoom, Bengal, India.
THOMSON, GEORGE, Bannockburn Colliery, Bannockburn, R.S.O., Stirlingshire.
THOMSON, JAMES, Ross Street, Dunfermline, N.B.
THOMSON, JOHN, Glenarm Lime Works, Larne, Co. Antrim.
THOMSON, JOHN, Eston Mines, by Middlesbrough.
THOMSON, JOS. F., Manvers Main Colliery, Wath-upon-Dearne, Rotherham.
THOMSON, RICHARD, Angle Cottage, Whifflet, Coatbridge, N.B.
THOMSON, R. D., Ibstock Colliery, Ashby-de-la-Zouch.
THOMSON, THOMAS, Crossford, Dunfermline, N.B.
THOMSON, THOMAS, Eddlewood Colliery, Hamilton, N.B.
THORNEWILL, ROBERT, Engineering Works, Burton-upon-Trent.
THORNEYCROFT, WALLACE, Merryton Colliery, Hamilton, N.B.
THORNTON, PETER, Crofthead Colliery, Fauldhouse, Linlithgowshire.
TINKER, J. J., Hyde, Manchester.
TODD, JOHN, Greenfield Terrace, Irvine, N.B.
TODD, JOHN T., Blackwell Collieries, Alfreton.
TODD, W. G., Nunnery Colliery Offices, Sheffield.
TOMLINSON, JOHN, Acres, Pilsley, Chesterfield.
TONKIN, J. J., Linares, Provincia de Jaen, Spain.
TOUZEAU, E. M., Leadenhall Buildings, Leadenhall Street, London, E.C.
TOWNSEND, HY. GEO., St. John's Colliery, Normanton.
TREADWELL, GEORGE A., Nevada City, California, U.S.A.
TREGLOWN, C. H., 38, Wretham Road, Handsworth, Birmingham

TRELEASE, W. HENWOOD, Pestarena United Gold-mining Company, Limited, Pestarena, Vall Anzasca, Novara, Italy.
TRESTRAIL, N., Claremont Road, Redruth, Cornwall.
TURBUTT, W. G., Ogston Hall, Alfreton.
TURNBULL, A. W., 130, George Street, Edinburgh.
TURNBULL, ROBERT, South Kirkby Colliery, Wakefield.
TURNER, GEORGE, Cardley House West Bromwich.
TURNER, JOHN, Moira Colliery, Ashby-de-la-Zouch.
TURNER, T. N., Langley Mill, Notts.
TURNER, WILLIAM JEPSON, The Chase, Charnwood, Whitwick, Leicester.
TYAS, A. R., Swaithe, near Barnsley.
TYERS, JOHN E., Singareni Collieries, c/o Hyderabad Deccan Company, Limited, Secundarabad, East India.

VALLANCE, WILLIAM, Ross Colliery, Ferniegair, Hamilton, N.B.
VARTY, THOMAS, Skelton Park Mines, Skelton, R.S.O., Cleveland.
VAUGHAN, CEDRIC, Hodbarrow Iron Ore Mines, Millom, Cumberland.
VEASEY, THOS. FRED., 5, Copthall Buildings, London, E.C.
VEASY, HARVEY C., Burrakur Coal Company, Limited, Barakar, Bengal, East India.
VEZIN, HENRY A., P.O. Box 256, Denver, Colorado, U.S.A.
VIGGARS, BENJAMIN D., Hope Cottage, Downing Street, Silverdale, Staffordshire.
VIGGARS, MATTHEW HENRY, Knutton Farm, Newcastle, Staffordshire.
VITANOFF, GEO. N., Sophia, Bulgaria.
VIVIAN, JOHN, Vivian's Boring and Exploration Co., Limited, 42, Lowther Street, Whitehaven.

WADDELL, ROBERT, 126, Onslow Drive, Glasgow.
WADDLE, H., The Waddle Patent Fan and Engineering Co., Limited, Llanelly, South Wales.
WADHAM, E., Millwood, Dalton-in-Furness.
WAIN, EDWARD B., Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
WAIN, J. R., Chatterley-Whitfield Collieries, Tunstall, Staffordshire.
WAIN, WM. HOLT, Cardiff Navigation Colliery, Llantrisant, Cardiff.
WALDIE, JAMES F., 114, Bath Street, Glasgow.
WALES, H. T., Pontypridd, South Wales.
WALKER, DAVID, Jun., Oxgang, Kirkintilloch, N.B.
WALKER, G. BLAKE, Wharncliffe Silkstone Colliery, Barnsley.
WALKER, JAMES P., Ardoon, Dunaskin, Ayrshire.
WALKER, J. S., Pagefield Iron Works, Wigan, Lancashire.
WALKER JOHN W., Bog Colliery, Larkhall, R.S.O., Lanarkshire.
WALKER, PETER, 3, Tweed Street, West Calder, R.S.O., Midlothian.
*WALKER, ROBERT, Fairholm Colliery, Larkhall, R.S.O., Lanarkshire.
WALKER, THOMAS A., Pagefield Iron Works, Wigan.
WALKER, W., Hawthorns, Saltburn-by-the-Sea.
WALKER, WILLIAM, Cadzow Colliery, Hamilton, N.B.
WALKER, WILLIAM, Lowes Hill, Ripley, near Derby.
WALKER, WM., Jun., H.M. Inspector of Mines, Durham.
WALKER, W. E., Hall Street, Dudley, Worcestershire.
WALKER, WILLIAM EDWARD, Lowther Street, Whitehaven.
WALKER, W. H., Springwells Colliery, Airdrie, N.B.

WALL, HENRY, Rowbottom Square, Wallgate, Wigan.
WALLACE, HENRY, Trench Hall, Gateshead-upon-Tyne.
WALLACE, J., King Street, Wigan.
WALLACE, JAMES, Wester Gartshore Colliery, Kirkintilloch, Glasgow
WALLACE, ROBERT.
WALLAU, JACOB, 68, Coatsworth Road, Gateshead-upon-Tyne.
WALLWORK, JESSE, Haydock Collieries, St. Helen's, Lancashire.
WALSH, G. P., 564, Heirengracht, Amsterdam, Holland.
WALTERS, HARGRAVE, Birley Collieries, Sheffield.
WALTERS, J. T., Babbington Collieries, Nottingham.
WALTON, J. COULTHARD, Writhlington Colliery, Radstock, *via* Bath.
WALTON, THOMAS, Habergham Colliery, Burnley.
WALTON, W. W., Croft Cottage, Ferryside, near Carmarthen, South Wales.
WANLESS, BATEMAN, Garforth Colliery, Leeds.
WAPLINGTON, WILLIAM, Glyncastle Collieries, Resolven, Neath.
WARBURTON, J. S., 19, Stanwick Road, West Kensington, London, W.
WARD, A. H., c/o Bengal Coal Company, Limited, Calcutta, India.
WARD, F. L., Bradford Colliery, Bradford, Manchester.
WARD, H., Rodbaston Hall, near Penkridge, Stafford.
WARD, T. H., Kabribad, Giridih, E.I. Railway, Bengal, India.
WARDELL, S. C., Doe Hill House, Alfreton.
WARDLAW, JOHN, Stanley Cottage, Newmains, N.B.
WARDLAW, ROBERT, Kersland Colliery, Dalry, Ayrshire.
WARDLE, W., West Cannock Colliery, Hednesford, Staffordshire.
WARING, G. W., 17, Grange Road, Dudley, Worcestershire.
WARRINGTON, JAMES HENRY, Berry Hill Works, Stoke-upon-Trent.
WASHINGTON, W., Mitchell Main Colliery, Barnsley.
WATERHOUSE, M. W., Glass Houghton Colliery, Castleford.
WATKYN-THOMAS, W., Workington.
WATSON, ADAM, c/o Blane & Co., P.O. Box 435, Johannesburg, Transvaal.
WATSON, ANDREW, Cadzow Colliery, Hamilton, N.B.
WATSON, EDWARD, South Pelaw Colliery, Chester-le-Street.
WATSON, Sir JOHN, Bart., Earnock, Hamilton, N.B.
WATSON, JOHN, Langlaagte Estate and Gold-mining Co., Limited, P.O. Box 98, Johannesburg, Transvaal.
WATSON, JOHN G., Ivy Bank, Armadale Station, Linlithgowshire.
WATSON, SIMEON, New Hucknall Colliery, Mansfield.
WATSON, T., Trimdon Colliery, Trimdon Grange.
WATSON, WILLIAM, Annesley, Uddingston, Glasgow.
WATSON, WILLIAM, Livingstone Terrace, Uddingston, Glasgow.
WATTS, JOHN.
WAUCHOPE, J. A., Auckland, New Zealand.
WEBSTER, DAVID, Burdiehouse Limeworks, Loanhead, Midlothian.
WEBSTER, H. INGHAM, Morton House, Fence Houses.
WEEKS, Jos. D., Pittsburg, Pa., U.S.A.
WEEKS, J. G., Bedlington, R.S.O., Northumberland.
WEEKS, R. L., Willington, Co. Durham.
WEIR, ALEXANDER, Fireclay Works, Castlecary Station, Glasgow.
WEIR, ROBERT, Camp Colliery, Motherwell, N.B.
WEIR, WILLIAM, 33, Anderson Street, Cambusnethan, Wishaw, N.B.
WELLS, W. E., Eckington Collieries, Sheffield.

WEMYSS, R. E., Wemyss Castle, Fifeshire.
WESTERN, C. R., Broadway Chambers, Westminster, London, S.W.
WHEATLEY, SAMUEL, Nailstone Colliery, Leicestershire.
WHEATLY, SAMUEL W., Butterton, Newcastle, Staffordshire.
WHITE, C. E., Wellington Terrace, South Shields.
WHITE, GEO., Estate Office, Mexboro', near Rotherham.
WHITE, H., Walker Colliery, Newcastle-upon-Tyne.
WHITE, H. BARTLETT, P.O. Box 24, Johannesburg, Transvaal.
WHITE, I. W. H., Bedford House, Roundhay, Leeds.
WHITE, J. F., 15, Wentworth Street, Wakefield.
WHITEHEAD, JAMES, Brindle Lodge, near Preston, Lancashire.
WHITEHEAD, JOHN, Jun., Bexton Road, Knutsford, Cheshire.
WHITEHEAD, JOHN JAMES, 85, Haworth Buildings, Cross Street, Manchester.
WHITEHOUSE, W. H., Brownhills, Walsall.
WHITELAW, JOHN, 118, George Street, Edinburgh.
WHITELAW, THOMAS, 112, Wellington Street, Glasgow.
WHITESIDE, JOHN, The Bothwell Coal Co., Limited, Holytown, N.B.
WHITTEM, THOMAS S., Wyken Colliery, near Coventry.
WHYTE, ROBERT, Clyde Wire Rope Works, Rutherglen, Glasgow.
WIDDAS, C., North Bitchburn Colliery, Howden, Darlington.
WIGHT, EDWD. S., Kiripaka, near Auckland, New Zealand.
WIGHT, W. H., Cowpen Colliery, Blyth.
WILCOX, H., Miners' Safety Explosive Works, Stanford-le-Hope, Essex.
WILDE, W., Rockingham Colliery, Barnsley.
WILDE, WILLIAM, Brockett House, Sharrow, Sheffield.
WILKES, JOHN S., Pelsall, near Walsall, Staffordshire.
WILKIE, NEIL A., Nethercroft Mines, Croy, Glasgow.
WILKINSON, J. R., Spark Lane, Mapplewell, Barnsley.
WILKINSON, THOMAS, Tinsley, near Sheffield.
WILLIAMS, EDMUND W., Henshall House, Goldenhill, Stoke-upon-Trent.
WILLIAMS, ERNEST, P.O. Box 965, Bittelheim Buildings, Simmonds Street, Johannesburg, Transvaal.
WILLIAMS, GARDNER F., De Beers Consolidated Mines, Limited, Kimberley, South Africa.
WILLIAMS, HERBERT IGNATIUS, Goldenhill, Stoke-upon-Trent.
WILLIAMS, H. J. CARNEGIE, c/o J. McDonald, 43, Threadneedle Street, London, E.C.
WILLIAMS, J., 115, Wellington Road, Dudley, Worcestershire.
WILLIAMS, R., The Johnson's Reef Gold Mines Company, N.L., California Gully, Bendigo, Victoria, Australia.
WILLIAMSON, J., The Hills, Cannock, Staffordshire.
WILLIAMSON, J. H., Henshall House, Goldenhill, Stoke-upon-Trent.
WILLIAMSON, R., Park Hill Colliery, Wakefield.
WILLIAMSON, R. S., Cannock Wood House, Hednesford, Staffordshire.
WILLIAMSON, THOMAS, West Hallam Collieries, Ilkeston.
WILLIAMSON, WILLIAM, Opal Cottage, Burnblea, Hamilton, N.B.
WILLIAMSON, W. DUNCAN, 2A, Providencia No. 7, City of Mexico.
WILSON, BENJAMIN, The Mapperley Colliery Company, Limited, Stanley Pit, West Hallam, Derbyshire.
WILSON, GEORGE, 6, Chapelside Place, Airdrie, N.B.
WILSON, JOHN, Craigmount, Kelvinside, Glasgow.
WILSON, J. B., Wingfield Iron Works and Colliery, Alfreton.

WILSON, JOHN R. ROBINSON, H.M. Inspector of Mines, Leeds.
WILSON, JOSH. M., St. John's Colliery, Normanton.
WILSON, JOSEPH R., 1001, Chesnut Street, Philadelphia, U.S.A.
WILSON, LLOYD, Flimby Colliery, Maryport.
WILSON, P. O., Klerksdorp, South Africa.
*WILSON, ROBERT, Candie House, Avonbridge, Stirlingshire.
WILSON, ROBERT, Bathville Collieries, Armadale, N.B.
WILSON, W. B., Thornley Colliery, Thornley, R.S.O., Co. Durham.
WILSON, W. E. C., Shipley Collieries, Derby.
WINCHELL, HORACE V., 1306, S.E. 7th Street, Minneapolis, Minn., U.S.A.
WINGATE, JOHN B., 208, St. Vincent Street, Glasgow.
WINSTANLEY, PETER, Shaw Cross Colliery, near Dewsbury.
WINSTANLEY, ROBT., 28, Deansgate, Manchester.
WINTER, T. B., Grey Street, Newcastle-upon-Tyne.
WITHERS, CHARLES, 65, Station Street, Nottingham.
WITTY, H. SYKES, Denaby Main Colliery, Mexboro', near Rotherham.
WOLSTENHOLME, M., Llanfoist House, near Abergavenny.
WOOD, C. L., Freeland, Forgandenny, Perthshire.
WOOD, E. S., c/o Bengal Coal Company, Old Court House Street, Calcutta, India.
WOOD, JAMES, 28, Royal Exchange Square, Glasgow.
WOOD, JOHN, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
WOOD, JNO., Barley Brook Foundry, Wigan.
WOOD, LINDSAY, The Hermitage, Chester-le-Street.
WOOD, THOMAS, North Hetton Colliery Office, Moorsley, Hetton-le-Hole, R.S.O.
WOOD, THOMAS.
WOOD, T. P., Market Place, Chesterfield.
WOOD, W. H., Coxhoe Hall, Coxhoe, Co. Durham.
WOOD, WALTER J., Bengal Coal Company's Colliery, Rancegunge, Bengal, India.
WOOD, WALTER K., Broomhouse Colliery, Broomhouse, Glasgow.
WOOD, W. O., South Hetton, Sunderland.
WOODBURN, J. ALLAN, Lydenburg (Transvaal) Gold Exploration Company, Limited, Pilgrim's Rest, South African Republic.
WOODBURNE, T. J., De Beers Consolidated Mining Company, Limited, Kimberley, South Africa.
WOODHEAD, ALF., Low Moor Iron Works, Bradford.
WOODHEAD, L., Beeston Colliery, Leeds.
WOODWARD, HARRY P., c/o Messrs. Bewick, Moreing, & Co., Coolgardie, Western Australia.
WOODWORTH, BENJAMIN, Heron Cross, Fenton, Stoke-upon-Trent.
WOOLCOCK, J. H., 49, Lowther Street, Whitehaven.
WORDSWORTH, ROBERT, Warora Colliery, Central Provinces, India.
WORDSWORTH, T. H., New Moss Colliery, Audenshaw, near Manchester.
WORMALD, C. F., Mayfield Villa, Saltwell, Gateshead-upon-Tyne.
WORMALD, HENRY, Featherstone, Pontefract.
WORTH, F. G., 63, Queen Victoria Street, London, E.C.
WRIGHT, HENRY, Coolgardie, Western Australia.
WRIGHT, JOSEPH, Arboretum Street, Nottingham.
WRIGHTSON, T., Stockton-upon-Tees
WROE, JAMES, Sutton Colliery, Mansfield, Notts.
WROE, JONATHAN, Wharncliffe Silkstone Colliery, Barnsley.
WYNNE, T. TRAFFORD, Stone, Staffordshire.

WYPER, JAMES, Townlands Colliery, Hamilton, N.B.
WYSEHALL, GEORGE E., Kaiping Mines, c/o H.B.M. Consulate, Tientsin, North China.

YATES, JOHN, c/o The African Gold Recovery Company, Limited, Commissioner Street, Johannesburg, Transvaal.
YEOMAN, THOMAS P., Manager, Bengal Coal Company's Collieries, Laikdih, E.I.R., Bengal, India.
YOUNG, JOHN, Baljaffray Colliery, Bearsden, Glasgow.
YOUNG, JOHN, The British Gas Light Co., Limited, Etruria, Stoke-upon-Trent.
YOUNG, JOHN A., 7, Tyne Vale Terrace, Gateshead-upon-Tyne.
YOUNG, J. H., Wearmouth Colliery, Sunderland.
YOUNG, ROBERT, Durham Mines, King County, Washington State, U.S.A.

ZUMBULOGLON, G. C., Mahmoudie-Han, Stamboul, Turkey.

Associate Members.

* Deceased.

AINSWORTH, HARRY S., "Belvedere," Marine Terrace, Geraldton, Western Australia.
ALLHUSEN, ALFRED, Musgrave House, Gateshead-upon-Tyne.
ANDERSON, J. SCOTT, 53, Waterloo Street, Glasgow.
APPLEYARD, HENRY, c/o W. Firth, Water Lane, Leeds.
ARCHIBALD, J. W., Coolgardie, Western Australia.
ARMSTRONG, J. H., St. Nicholas' Chambers, Newcastle-upon-Tyne.
ARMSTRONG, T. J., Hawthorn Terrace, Newcastle-upon-Tyne.
ATKINSON, G. B., Prudential Assurance Buildings, Mosley Street, Newcastle-upon-Tyne.
AUDUS, T., Mineral Traffic Manager, North Eastern Railway, Newcastle-upon-Tyne.

BAGSHAW, F., 4, Ash Grove, Headingley, Leeds.
BANYER, B. R., Kapunda, South Australia.
BELL, HUGH, Middlesbrough-upon-Tees.
BENEKÉ, GEORGE, 70, Gracechurch Street, London, E.C.
BIGGE, EDWARD ELLISON, General Mining Association, Dashwood House, 9, New Broad Street, London, E.C. Transactions, etc., to be sent to R. H. Brown, Sydney Mines, Cape Breton, Nova Scotia.
BLENKIRON, J. E., 3, Albert Terrace, Middlesbrough.
BLUE, A., Bureau of Mines, Toronto, Ontario, Canada.
BURDON, A. E., Hartford House, Cramlington, Northumberland.

CARR, ARTHUR D., Whickham Rectory, Whickham, R.S.O.
CARR, WM. COCHRAN, Lower Condercum, Benwell-upon-Tyne.
CHAPMAN, C. W., The Australian Smelting Company, Limited, 372, Flinders Lane, Melbourne, Australia.
CHEWINGS, CHARLES, Coolgardie, Western Australia.
COCHRANE, R. D., Hetton Colliery Offices, Fence Houses.
COOPER, E. F. X., c/o The Natal Bank, 156 and 157, Leadenhall Street, London, E.C.

Cooper, R. W., Newcastle-upon-Tyne.
Cox, P. M., Stoke-upon-Trent.

Davenport, J. E., The Elms, Oulton, Leeds.
Depledge, W. T., The Lodge, Stanley, Wakefield.
Dodds, A. P., 13, Dean Street, Newcastle-upon-Tyne.
Duignan, W. H., Gorway House, Walsall.
Duncan, G. T., 96, Brighton Grove, Newcastle-upon-Tyne.
Dunston, George, Hatfield Grange, Doncaster.

Eccles, Edward, King Street, Newcastle-upon-Tyne.
Edwards, F. H., Forth House, Bewick Street, Newcastle-upon-Tyne.

Findlay, Matthew F., 41, Ann Street, Glasgow.
Firth, John G., Hunslet New Road, Leeds.
Firth, William, Water Lane, Leeds.
Foster, T. J., Coal Exchange, Scranton, Pennsylvania, U.S.A.

Gue, T. R., P.O. Box 520, Halifax, Nova Scotia.
Guthrie, Reginald, Neville Hall, Newcastle-upon-Tyne.
Gwyn, A. E. W., 114a, Queen Victoria Street, London, E.C.

Hedley, E., Rainham Lodge, The Avenue, Beckenham, Kent.
Hedley, J. Hunt, John Street, Sunderland.
Heeley, George, 34, Oxford Street, Sheffield.
Henderson, C. W. C., The Riding, Hexham.
Henzell, Robert, Close, Newcastle-upon-Tyne.
Heyworth, Col. Lawrence, Ormsby Hall, Alford, Lincolnshire.
Hickman, E., Stone Quarries, Bilston.
*Hicks, James, Redruth, Cornwall.
Hodgkinson, W. D., Newthorpe, Notts.
Hopper, J. I., Wire Rope Works, Thornaby-upon-Tees.
Humble, Stephen, Jun., 9, Victoria Street, Westminster, London, S.W.
Humphreys-Davies, G., 8, Laurence Pountney Hill, Cannon Street, London, E.C.
Hunter, C. E., Selaby Park, Darlington.

I'Anson, James, Fairfield House, Darlington.
Ingold, Herbert, c/o W. Cooke & Co., Limited, Tinsley Steel and Iron Works, Sheffield.
Inman, F. L., Poste Restante, Johannesburg, Transvaal.

James, H. M., Colliery Office, Whitehaven.
Joicey, James John, Sunningdale Park, Berks.

Kirkup, Fred. O., Bitchburn Colliery, *via* Crook, R.S.O., Co. Durham.
Krohn, H. A., 103, Cannon Street, London, E.C.

Larsen, A., The Carbonite Syndicate, Limited, 24, Queen Victoria Street, London, E.C.

Middleton, R. J., Broad Street House, London, E.C.

O'DONAHUE, T. A., 35, Princess Street, Wigan.

PALMER, A. M., 1, Jesmond High Terrace, Newcastle-upon-Tyne. Transactions to Secretary, Anglo-American Club, Freiberg, Saxony, Germany.
PATTERSON, WM., 5, Hardwicke Terrace, Gateshead-upon-Tyne.
PEARSON, ALFRED, Estate Office, Dukinfield, Manchester.
PEASE, ARTHUR, Darlington. Transaction to be sent to the Librarian, Ed. Pease Free Library, Darlington.
PERKINS, CHARLES, Gallowhill Hall, Newcastle-upon-Tyne.
PROCTOR, J. H., 22, Hawthorn Terrace, Newcastle-upon-Tyne.

RICHTER, F., Osborne Villas, Newcastle-upon-Tyne.
RIDLEY, J. C., 3, Summerhill Grove, Newcastle-upon-Tyne.
RIDLEY, Sir MATTHEW WHITE, Bart., M.P., Blagdon, Northumberland.
RITSON, J. R., Burnhope Colliery, Lanchester.
ROGERSON, JOHN E., Oswald House, Durham.

SAUNDERS, G. B., c/o Messrs. Dawson, Saunders, and Todd, Maritime Buildings, Newcastle-upon-Tyne.
SCURFIELD, GEORGE J., Hurworth-upon-Tees, Darlington.
SHAW, SAVILLE, Durham College of Science, Newcastle-upon-Tyne.
SMITH, C. A., 20, Alexandra Place, Newcastle-upon-Tyne.
SNOWBALL, FRANCIS JOHN, Seaton Burn House, Dudley, Northumberland.
STANDRING, P. W. D., Strafford Collieries, Barnsley.
SWINBURNE, U. P., c/o Rd. Chamberlain, 39, Cadogan Square, London, S.W.

TAYLOR, J. HOWARD, Coolgardie, Western Australia.
THOM, JOHN, Canal Works, Patricroft, near Manchester.
THOMPSON, EDWARD, 38, Melton Road, Bridgford, Nottingham.
TODD, JAMES, Elvet Bridge, Durham.
*TURNER, G. W., The Farm, Northwingfield, Chesterfield.

WALL, G. YOUNG, Halmote Court Office, New Exchequer Buildings, Durham.
WALMSLEY, OSWALD, 2, Stone Buildings, Lincoln's Inn, London, E.C.
WALTON, JAMES, 23, Queen Street, Newcastle-upon-Tyne.
WARD, JOHN, Stafford Street, Longton, Staffordshire.
WATSON, ARTHUR, Burnopfield, Co. Durham.
WEATHERBURN, J., 14, Stirling Terrace, Saltwell Lane, Gateshead-upon-Tyne.
WEDGWOOD, LEVESON, North Road, Cobridge, Stoke-upon-Trent.
WILLIAMS, THOMAS, Halesowen.
WILSON, A. P., Mansion House Chambers, Queen Victoria Street, London, E.C.
WOOD, E. P., Synher Villa, Crafthole, St. Germans, Cornwall.

Associates.

* Deceased.

AUSTIN, T. W., Stanton Hill, Mansfield.

BAILEY, J. H., New Buildings, Dordon, Tamworth.
BAINBRIDGE, J., North Walbottle Colliery, Newcastle-upon-Tyne.
BAKER, GEORGE, Bedlington Colliery, Bedlington, R.S.O.
BALL, G. B., New Street, Hilcote, Blackwell, Alfreton.

BALL, JOSEPH, Amber Terrace, Wessington, near Alfreton.
BALL, JOSIAH, Teversal Collieries, Mansfield.
BARBER, JOSEPH, Ansley Hall Colliery, Atherstone.
BARRASS, M., Tudhoe Colliery, Spennymoor.
BATTEY, THOMAS, Percy Terrace, Backworth Colliery.
BELL, J., Wardley Colliery, Newcastle-upon-Tyne.
BELL, W. R., Wearmouth Colliery, Sunderland.
BENTLEY, GEORGE, Bradford Colliery, Manchester.
BERRY, THOMAS, 1, Middleton, Swalwell, R.S.O.
BLAIKIE, JOHN, Whitebarn Colliery, Newcastle, Staffordshire.
BLAIR, HENRY, Steel's Lane, Brimington Common, Chesterfield.
BLOOD, JOHN, Bentinck Houses, Kirkby in Ashfield, Nottingham.
BOLAM, J. T., The View, Beamish, Chester-le-Street.
BOOTH, AARON, Blackwell Collieries, Alfreton.
BOWES, THOMAS, Pontop House, Annfield Plain, R.S.O.
BOWMAN, FRANK, Auckland Park Colliery, near Bishop Auckland.
BRAMLEY, WILLIAM, Dale Abbey, Stanton-by-Dale, Nottingham.
BROWN, JOHN, 13, West Street, Brandon Colliery, Co. Durham.
BROWN, R. O., Throckley Colliery, near Newcastle-upon-Tyne.
BURDETT, J. C., Nailstone Colliery, Leicester.
BUTTERWORTH, GEORGE, Egstow, Market Street, Clay Cross, Chesterfield.
BUXTON, SIMEON, Granville Colliery, Swadlincote, Burton-upon-Trent.

CHAMBERS, JAMES, Cavendish Villas, Portland Road, Hucknall Torkard, Notts.
CLAMP, ELIJAH, Birch Coppice Colliery, near Tamworth.
CLARE, HENRY, Birchenwood Colliery Company, Limited, Kidsgrove, Stoke-upon-Trent.
CLARK, THOMAS, Dipton Colliery, Lintz Green Station.
CLAY, ZECHARIAH, New Watnall, Nottingham.
COCKBURN, EVAN, Page Bank Colliery, *via* Spennymoor, Durham.
COLLINS, W. F., Netherseal Colliery, Burton-upon-Trent.
COWELL, J. S., Wearmouth Colliery, Sunderland.
COWX, H. F., Thornley Collieries, *via* Trimdon Grange, R.S.O.
CROWN, WILLIAM, 29, Fifth Row, Ashington Colliery, Morpeth.
CUTTS, GEORGE, Lowes Hill, Ripley, Derby.

DAVIES, SAMUEL, Barrow Farm, Worsborough, near Barnsley.
DAVIS, THOMAS, New Higham, Alfreton.
DIXON, JOSEPH A., Ellison Road, Dunston.
DORMAND, RALPH B., Waldridge Colliery, Chester-le-Street.
DOWNING, JOHN, Rockingham Colliery, Barnsley.
DRAPER, W., New Seaham Colliery, Sunderland.
DRAYCOTT, JOSEPH, Alfreton Colliery, Alfreton.
DUNNETT, SAMUEL, Cambois Colliery, Northumberland.

ELLIOTT, DANIEL, Houghton Main Colliery, Barnsley.
ELLIOTT, J. W., Kirkby Colliery, Kirkby-in-Ashfield, Nottingham.
ELTRINGHAM, GEORGE, Shire Moor Colliery, Newcastle-upon-Tyne.
EMERSON, R., Tudhoe Colliery, Spennymoor.
ENZOR, WILLIAM, Morton, Alfreton.
EVANS, WILLIAM, Cliffe Vale, Stoke-upon-Trent.

FAIRS, JOHN, Escomb Bridge, Bishop Auckland.
FAWCETT, EDWARD, 27, Eastbourne Gardens, Walker-upon-Tyne.
FERGUSON, KENNETH, Clay Cross Collieries, Chesterfield.
FINCH, W. W., The Lewdin Colliery Co., Worsboro' Dale, Barnsley.
FOSTER, J. W., 24, Silksworth Terrace, New Silksworth, Sunderland.
FOSTER, THOS., Oaks Colliery House, near Barnsley.
FRYAR, J. W., Seghill Colliery, Seghill, Northumberland.

GORDON, G. S., 24, Louisa Terrace, Stanley, R.S.O., *via* Chester-le-Street.
GRAY, W. J., Birley Collieries, Sheffield.
GREENE, JOHN, Priors Lee, Shifnal, Shropshire.
GRIFFIN, GEORGE, Parkside, Market Street, Clay Cross, Chesterfield.

HADLEY, WM., Shelton Steel and Iron Co., Stoke-upon-Trent.
HALBAUM, H. W., 23, Bateman Street, Derby.
HALL, GEORGE, 36, Compton Street, Chesterfield.
HARLE, R. A., Wallsend Colliery, Wallsend-upon-Tyne.
HARRISON, GEORGE, High Park Colliery, Greasley, Nottingham.
HEATH, A. S., Adderley Green Collieries, Stoke-upon-Trent.
HEDLEY, A. M., Medomsley, R.S.O., Co. Durham.
HENDERSON, WILLIAM, Wheatley Hill Colliery, *via* Trimdon Grange.
HENRY, JAMES, Howgill Staith, Whitehaven.
HENSHAW, JOHN, Butterley Park, Alfreton.
HEPBURN, T., The Firs, Langley Park, Durham.
HERRON, EDWARD, 4, Holly Terrace, Stanley, R.S.O.
HESLINGTON, ALFRED, New Tupton, Chesterfield.
HEWITT, JOSEPH, Heron Cross, Fenton, Stoke-upon-Trent.
HIGGINBOTTOM, REGINALD, c/o J. Fairley, Shafto House, Chester-le-Street.
HILL, WILLIAM, Manor Street Foundry, Fenton, Stoke-upon-Trent.
HINDMARCH, JOHN, Isabella Pit, Newsham, Blyth.
HOBSON, MOSES, Shildon, *via* Darlington.
HODGSON, E., Black Boy Colliery, Bishop Auckland.
HODGSON, L. H.
HODSON, JAMES E., Furnace Road, Normacot, Stoke-upon-Trent.
HUGHES, A. E., Lea Terrace, Union Road, Newhall, Burton-upon-Trent.
HUGHES, WILLIAM, Springwood, Chesterton, Staffordshire.
HULETT, CHARLES T., Lilleshall Collieries, St. Georges, Wellington, Salop.
HUNTER, CHRISTOPHER, 18, Stanley Street, Blyth, Northumberland.
JAMES, A. A., Croxdale, near Durham.
JEPSON, W. W., Mexboro' House, Selston, Alfreton.
JOHNSON, WM., Framwellgate Moor, Durham.
KENYON, G. C., Sandygate, Wath-upon-Dearne, Rotherham.
KIRK, SAMUEL, Colliery Yard, Cinderhill, Nottingham.
KNIGHT, JOHN L., Adderley Green Collieries, Stoke-upon-Trent.
KNIGHTON, HERBERT, High Park, Newthorpe, Notts.

LAMBERT, R. W., Dolphin Hotel, Mushroom Lane, Sheffield.
LEBETER, ROBERT, Dordon, Tamworth.
LEE, JOHN, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
LIGHTLEY, JOHN, Front Street, Sherburn Colliery, Durham.
LINDAY, ROBERT, 3, Sebastopol Terrace, Seaham Harbour.
LINNEKER, J. G., Parkend, Lydney, Gloucestershire.

LISTER, R. L., Charity Collieries, Bedworth, Nuneaton.
LOCKETT, WILLIAM, West View, Park Road, Burslem, Staffordshire.
LONGDON, ALBERT, Newthorpe, Notts.
LONGSDALE, NIGEL, Harecastle and Woodshutts Colliery, Stoke-upon-Trent.
LOVE, WM. ALLEN, Cornsay Colliery, Co. Durham.

MACHIN, THOMAS, Teversal, Mansfield.
MACINTOSH, T., Watts Farm, Blyth.
MACKINLAY, E., East Stanley Colliery, Chester-le-Street.
MACRONE, HARRY WILSON, 16, Bank Street, Sheffield.
MASON, BENJ., Burnopfield Colliery, Burnopfield, R.S.O., Durham.
MEAKIN, JOSEPH, Mansfield Road, Eastwood, Notts.
MILBURN, WM., Cornsay House, Cornsay, Durham.
MILLER, J. H., South Hetton, Sunderland.
MILLERSHIP, J. H., Watnall Colliery, Watnall, Notts.
MINNIKIN, JOHN, Ivy Cottages, Hoyland Common, Barnsley.
MINTO, GEORGE W., Chapel Row, Ouston, Chester-le-Street.
MORDY, W., Shelton Iron, Steel, and Coal Co., Limited, Stoke-upon-Trent.
MORGAN, THOMAS, Hall End Colliery, near Tamworth.
MOSS, HENRY, 223, Derby Road, Nottingham.
MOULTON, LEVI, The Villas, Silverdale, Staffordshire.
MUIRHEAD, JAMES, Grove Road, Fenton, Stoke-upon-Trent.

NAISBIT, JOHN, 48, Tudhoe Colliery, Spennymoor.
NAYLOR, GEORGE E.
NAYLOR, JOHN, Cotes Park Colliery, Alfreton.
NICHOLSON, A. D., Lane Ends, Hetton-le-Hole, R.S.O., Co. Durham.

PARKER, HENRY, Godley Brook, Dilhorne, Stoke-upon-Trent.
PARKINSON, W., 6, Ivy Terrace, South Moor, Chester-le-Street.
PATRICK, J. A., West Pool Villas, Saltergate, Chesterfield.
PATRICK, THOMAS, Netherseal Colliery, Burton-upon-Trent.
PATTERSON, THOMAS, Craghead, Chester-le-Street
PEASGOOD, W. G., Leycett, Newcastle, Staffordshire.
PEDELTY, SIMON, Clara Vale, Ryton-upon-Tyne.
PERCIVAL, JOSEPH, Netherseal Colliery, Burton-upon-Trent.
PERCY, R. F., 76, Belvoir Crescent, Sneinton, Nottingham.
PRATT, G. ROSS, Springwell Colliery, Gateshead-upon-Tyne.
PROCTOR, THOMAS, Ashington Colliery, Northumberland.
PUGHE, W. A., The Farm, New Tupton, near Chesterfield.

RAMSAY, JOHN, Tursdale Colliery, Ferryhill.
RAMSAY, J. G., Page Bank Colliery, *via* Spennymoor, Co. Durham.
RATCLIFFE, WILLIAM, Beazley View, Chesterton, Newcastle, Staffordshire.
RAWSON, GEORGE, Tibshelf No. 2 Pit, Tibshelf, Alfreton.
REED, WILLIAM, Bagworth, Leicester.
REEVES, JAMES, Jun., High Carr House, Alvecote, Tamworth.
RIDLEY, G. D., Tudhoe Colliery, Spennymoor.
RIVERS, JOHN, Front Street, Tudhoe Colliery, Spennymoor.
ROBERTS, THOMAS, Brownhills Colliery, Tunstall, Staffordshire.

ROBINSON, GEORGE HERBERT, Wesley Place, Tunstall, Stoke-upon-Trent.
ROBINSON, GEORGE L., Adderley Green, near Longton, Staffordshire.
ROBSON, R., 2, Thornley Terrace, Tow Law, R.S.O., Co. Durham.
ROBSON, WILLIAM, Jun., Tow Law, R.S.O., Co. Durham.
ROEBUCK, WALTER, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.

SCOTT, E. CHARLTON, Rainton Colliery, Fence Houses.
SCOTT, WM., Thornhill Collieries, near Dewsbury.
SEVERN, THOMAS, Clifton Colliery, Nottingham.
SEVERS, WM., Beamish View, *via* Chester-le-Street.
SHAW, CHARLES, Jun., Woodland View, Froghall, Stoke-upon-Trent.
SHAW, JOHN, The Dolcoath Mine Limited, Camborne, Cornwall.
SHELDON, JOHN, Eastwood, Nottingham.
SHENTON, JOHN, Silverdale, Staffordshire.
SHORE, THOMAS, Ireland Colliery, Staveley, Chesterfield.
SHUFFLEBOTHAM, DANIEL, Biddulph Valley Collieries, Stoke-upon-Trent.
SHUTTLEWORTH, ARTHUR, Park Terrace, Worsbro' Park, near Barnsley.
SOAR, CHARLES, Granville Colliery, Swadlincote, Burton-upon-Trent.
SOUTHERN, J., Heworth Colliery, Newcastle-upon-Tyne.
SOUTHERN, J. C., Houghton Colliery, Fence Houses.
SPRY, JOHN, Murton Colliery, Co. Durham.
STEPHENSON, W., Quarry Houses, Winlaton, near Blaydon-upon-Tyne.
STOKOE, JAMES, 7, North Street, Murton Colliery, *via* Sunderland.
*STRICK, THOMAS SHEPHARD, Bar Hill, Madeley, Staffordshire.
SWALLOW, F. C., Simonside House, Simonside, South Shields.

TAIT, JAMES, South Kirkby Colliery, near Wakefield.
TARBUCK, HAROLD, 102, Kennington Avenue, Ashley Down, Bristol.
THOMPSON, JOSEPH, 12, The Avenue, Murton Colliery, Sunderland.
THOMPSON, J. W., Backworth Colliery, Newcastle-upon-Tyne.
TOMLIN, JOHN, Granville Colliery, Burton-upon-Trent.
TURNER, GEORGE, Cornsay Colliery, Co. Durham.

URWIN, JOHN, Inkerman House, Usworth Colliery, Co. Durham.

VARLEY, JOHN, Walker Street, Eastwood, Notts.

WAIN, JOSEPH, The Chatterley-Whitfield Collieries, Bucknall Collieries Bucknall, Stoke-upon-Trent.
WAINWRIGHT, GEO., Rock House, Talke, Stoke-upon-Trent.
WALLETT, THOMAS, 94, Charlton's Terrace, Guisbro', R.S.O., Yorkshire.
WALTON, M., Dearham Colliery, Carlisle.
WARDLE, RICHARD, Dunsil House, Fackley, Mansfield.
WATKIN, R., Cortonwood Colliery, Barnsley.
WATSON, THOMAS, East Hedley Hope, Tow Law, R.S.O.
WHARTON, GEORGE, Egstowe Terrace, Clay Cross, Chesterfield.
WILBRAHAM, AARON, Mexboro' Colliery, Selston, Alfreton.
WILLIAMSON, S. E., Netherseal Colliery, Burton-upon-Trent.
WILSON, JACOB, Hucknall Huthwaite, Mansfield.

WILSON, R. G., Pelton Colliery, Chester-le-Street.
WOODS, RICHARD, 6, Southfields Terrace, Pye Bridge, Alfreton.

ZELLER, C. VAN, Villar Oporto, Portugal.

Students.

ADAMS, CHARLES, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
ALLOTT, J. R. L., Kinsley House, Kinsley, Hemsworth, near Wakefield.
ALLPORT, E. A., Dodworth Grove, Barnsley.
ARCHER, M. W., Victoria Garesfield, Lintz Green, Co. Durham.

BOOTH, FRED. L., Ashington Colliery, Morpeth.
BRODHURST, B. L., Glapwell Colliery, Chesterfield.
BROMLEY, OLIVER, Florence Colliery, Longton, Staffordshire.
BURNE, CECIL A., South Hetton Colliery, near Sunderland.
BURY, CHARLES, The Dale, Conisborough, Rotherham.

CARPENTER, S. W., Trevatham, Albemarle Road, Beckenham, Kent.
CARTER, W. H., Glapwell Colliery, Chesterfield.
CHAMBERS, F. E., Kenwadih Colliery, Dhunbaid P.O., *via* Burrakur, E.I.R., Calcutta, India.
CHAPLIN, GEORGE P., The Durham College of Science, Newcastle-on-Tyne.
CHECKLAND, B. H., Hilcote Hall, Alfreton.
COCKIN, T. H., Tinsley Park Colliery, Sheffield.
COWAN, HENRY D., Elswick Collieries, Newcastle-upon-Tyne.

DAVY, G. C. H., Manvers Main Colliery, Wath, near Rotherham.
DAVY, G. H., Wildfontein, District Middelburg, Transvaal.
DENTON, JOHN, Netherseal Colliery, Burton-upon-Trent.
DOUGLAS, DAVID, East Hetton Colliery, Coxhoe, R.S.O., Co. Durham.
DREW, WALTER N., Tankersley Cottage, Wharncliffe Silkstone, Barnsley.

EAMES, WILLIAM, Rose Cottage, Midland Road, Nuneaton.
ELLISON, C. C., Wharncliffe Silkstone Collieries, Tankersley, Barnsley.
FALCON, MICHAEL, 23, Cemetery Road, Treorchy, South Wales.
FORSTER, J. H. B., Hetton Colliery, Hetton-le-Hole, R.S.O., Co. Durham.
FOWLER, G. C., Cliff Houses, Cinder Hill, Nottingham.
FRITH, REG., c/o Roodeport Deep Level Company, P.O. Box 1488, Johannesburg, Transvaal.

GOODALL, E. M., Eckington Collieries, Sheffield.
GRAZEBROOK, A. W., Queen's Cross, Dudley, Worcestershire.
GREENE, CHARLES C., South Durham Colliery, Eldon, Bishop Auckland.
GREGORY, JOHN, Sneyd Colliery, Burslem, Stoke-upon-Trent.
GRIFFITH, N. MAURICE, The Broughton and Plas Power Coal Co., Limited, near Wrexham.

HALL, R. O., Treeton, Rotherham.
HALPIN, W. L., Blackwell Collieries, Alfreton.
HANCOCK, J. G., Bolsover Colliery, Chesterfield.
HARBIT, W. D., 32, High Street, Wallsend-upon-Tyne.
HEATHCOTE, C. H., Newstead Colliery, Nottingham.
HETHERINGTON, J. RIDLEY, c/o Mrs. Burnley, Sisters Villas, Garforth Colliery, near Leeds.
HIRST, G. F., Rotherham Main Colliery, near Rotherham.
HOMER, J. EDWARD, Wheatley Bank, Bucknall, Stoke-upon-Trent.
HOWARTH, JAMES C., 2, Lendel Terrace, Paisley Road, Glasgow.

IMESON, J. A., Wearmouth Colliery, Sunderland.

JONES, WILLIAM, Trimdon Grange Colliery, Trimdon Grange, R.S.O.

KING, FRED., South Farm, Cramlington, Northumberland.
KIRKUP, AUSTIN, Bunker Hill, near Fence Houses.
KNIGHT, FRANCIS W., Newcastle, Staffordshire.

LATIMER, HUGH, South Durham Colliery, Eldon, Bishop Auckland.
LAWTON, T. A., Brynkinalt Collieries, Chirk, North Wales.
LEACH, G. C., Birchill Lodge, Hasland, Chesterfield.
LEWIS, RALPH, 11, Park Crescent, Falmouth, Cornwall.
LISHMAN, T. A., Eppleton Hall, Hetton-le-Hole, R.S.O., Co. Durham.
LITTLEJOHN, ALBERT, "Hawthorn," Manly, Sydney, New South Wales.
LONGBOTHAM, CHARLES E., Barrow Collieries, Barnsley.
LONGDEN, G. A., Stanton-by-Dale, Nottingham.
LYNAM, R. B., Shelton Steel and Iron Co., Stoke-upon-Trent.
LYON, J. W., The Firs, Annesley, Nottingham.

MCGOWAN, ERNEST, Wearmouth Colliery, Sunderland.
MAKEPEACE, R. R., Newcastle, Staffordshire.
MARSHALL, C. C., Gayton Hall, Ross, Herefordshire.
MASCALL, W. H., Joanroyd Colliery, Heckmondwike.
MIDDLETON, H. W., Trimdon Grange Colliery, Trimdon Grange, R.S.O., Co. Durham.
MITCHESON, HARRY, Dresden, Longton, Staffordshire.
MITTON, H. E., Upper Langwith, Mansfield.
MOLLER, W. A., Shanghai, China.
MORTON, CHARLES PERCY, Waleswood Colliery, near Rotherham.
MOXON, J. B., The Beeches, Rugeley.
MUSGROVE, WILLIAM, Throckley Colliery Office, Throckley Colliery, near Newcastle-upon-Tyne.

NEASHAM, PHILIP, Park View, Leadgate, Co. Durham.
NICHOLAS, C. COWELL, 14, Avenue Road, Doncaster.
NISBET, NORMAN, East Tanfield, Tantobie, R.S.O., Durham.
NIXON, JOHN, Stafford Coal and Iron Co., Stoke-upon-Trent.
NOBLE, ALGERNON, Broomhill Colliery, Acklington, Northumberland.
NUTTALL, P. N., Oakwell Colliery, Ilkeston.

PARRINGTON, T. E., Holywell Hall, Durham.
PAYNE, H. G., 23, Bassett Street, Camborne, Cornwall.
PEAKE, F. G., Walsall Wood Colliery, Walsall.
PEEL, J. W., Coundon, Bishop Auckland.
POPHAM, J. L., Winterbourne, Bournemouth.

RAINE, FRED. J., Cornsay Colliery, Co. Durham.
RATCLIFFE, PERCY, Tibshelf, Alfreton.
REES, J. H., The Avenue, Meir, Longton, Staffordshire.
RICHARDSON, M. D. R., Bestwood Colliery, Notts.
ROBERTS, F. F., Sutton Colliery, Sutton-in-Ashfield, Nottingham.
ROBINSON, F. K., Ellistown Collieries, near Leicester.
ROBSON, H. D., c/o L. F. R. and C. Goldfields, Limited, Vancouver, British Columbia.

SAMPLE, J. BERTRAM, South Tanfield Colliery, Stanley, R.S.O., Newcastle-upon-Tyne.
SAVAGE, A. T. C., Tibshelf Collieries, Alfreton.
SAXTON, ISAAC, Hasland, Chesterfield.
SEVERS, JONATHAN, Stanley, R.S.O., Newcastle-upon-Tyne.
SHAW, EDGAR H., Adderley Green Collieries, Stoke-upon-Trent.
SHERWEN, J. H., Whitehaven Collieries, Whitehaven.
SIMPSON, NELSON A., Bradley Hall, Wylam-upon-Tyne.
SIMPSON, R. R., 11, Haldane Terrace, Jesmond, Newcastle-upon-Tyne.
SIMPSON, THOMAS V., Heworth Colliery, Felling, R.S.O., Co. Durham.
SMITH, ERNEST E., Chatterley Whitfield Collieries, Tunstall, Staffordshire.
SOUTHERN, STEPHEN, Heworth Colliery, Felling, R.S.O., Co. Durham.
STEELE, W. R., Barrow Collieries, Barnsley.
STRATTON, H. S., Cramlington Collieries, Northumberland.
SWALLOW, W. A., Bushblades House, Lintz Green.

TATE, W. O., Trimdon Grange, Co. Durham.
TAYLOR, WILLIAM, Tibberton Grange, Newport, Salop.
THORNTON, NORMAN, Pelton Village, Pelton Fell.
TURNER, D. N., Mansfield Woodhouse, Mansfield.

WADE, R. A., Annesley, Nottingham.
WADSWORTH, W. D., Jun., Newbold Road, Chesterfield.
WALL, GEORGE, St. Helens Colliery, Bishop Auckland.
WALTERS, R. G., Shirtcliff House, Woodhouse, Sheffield.
WATERS, EDWARD, Throckley Colliery, Newcastle-upon-Tyne.
WEBB, ROWLAND C., Kimberley Club, Kimberley, South Africa.
WHELER, AUBREY S., 3, Dolcoath Road, Camborne, Cornwall.
WHITTAL, H. E. C., Constantinople, Turkey.
WILKINSON, HORACE, 26, Gregory Street, Ilkeston.
WILLIS, HENRY STEVENSON, Whickham, R.S.O., Co. Durham.
WORMALD, ROBERT, Wishaw Colliery, Boksburg, Transvaal, South Africa.
WRIGHT, GEORGE, The Dale, Conisborough, Rotherham.

Subscribers.

ASHINGTON COLLIERY, OWNERS OF, Newcastle-upon-Tyne.
ATHERTON, JAMES, 13, Mawdsley Street, Bolton.

BIRTLEY IRON COMPANY, Birtley.
BRIDGEWATER TRUSTEES, Bridgewater Offices, Walkden, Bolton-le-Moors, Lancashire.
BUTE, MARQUESS OF, Bute Estate Office, Aberdare, South Wales.
BUTTERKNOWLE COLLIERY CO., LIMITED, Darlington.

COWPEN COAL CO., LIMITED, F, King Street, Newcastle-upon-Tyne.

THE LIBRARIAN, Public Library, Detroit, Michigan, U.S.A. (B. F. Stevens, 4, Trafalgar Square, Charing Cross, London).
DURHAM, EARL OF, Lambton Offices, Fence Houses.

ELSWICK COAL COMPANY, LIMITED, Newcastle-upon-Tyne.
EYRE AND SPOTTISWOODE, 5, Middle New Street, London, E.C.

HASWELL COAL CO., Haswell Colliery, Haswell, *via* Sunderland.
HETTON COAL COMPANY, Fence Houses.
HUTTON HENRY COAL COMPANY, LIMITED, 7, Bondgate, Darlington.

JOHNSTON, ANDREW, Minas de Rio Tinto, Provincia de Huelva, Spain.

KEGAN PAUL, TRENCH, TRUBNER, AND CO., LIMITED, Paternoster House, Charing Cross Road, London, W.C.
KING, H. S., AND CO., Newspaper Department, 65, Cornhill, London, E.C.

LONDONDERRY, MARQUIS OF, c/o V. W. Corbett, Londonderry Offices, Seaham Harbour.

MAYER, J. A., Buchhandlung, Aachen, Germany.
MECHANICS INSTITUTE, San Francisco, California, United States (B. F. Stevens, 4, Trafalgar Square, Charing Cross, London).
MELLON, H., Askam-in-Furness, Lancashire.
MILLS, Messrs. J., AND SONS, Limited, 23, Collingwood Street, Newcastle-upon-Tyne.

NORTH BRANCEPETH COAL CO., LIMITED, Crown Street Chambers, Darlington.
NORTH HETTON COLLIERY, OWNERS OF, Fence Houses.

RYHOPE COAL COMPANY, Ryhope Colliery, near Sunderland.

SEGHILL COLLIERY, OWNERS OF, Seghill, Northumberland.
SIMPKIN, MARSHALL, HAMILTON, KENT, AND CO., Limited, 4, Stationers' Hall Court, London, E.C.

SOUTH HETTON AND MURTON COLLIERIES, OWNERS OF, 50, John Street, Sunderland.
STECHERT, G. E., 2, Star Yard, Carey Street, London, W.C.
STELLA COLLIERY, OWNERS OF, Hedgefield, Blaydon-upon-Tyne.

THROCKLEY COLLIERY, OWNERS OF, Newcastle-upon-Tyne.

VICTORIA GARESFIELD COLLIERY, OWNERS OF, c/o George Peile, Shotley Bridge, Co. Durham.

WEARMOUTH COLLIERY, OWNERS OF, Sunderland.
WESTPORT COAL CO., LIMITED, Manager, Dunedin, New Zealand.
WILLIAMS AND NORGATE, 14, Henrietta Street, Covent Garden, London, W.C.

Non-Federated.

* Deceased.

ADAM, WILLIAM, Blantyre Saw Mills, High Blantyre, Glasgow.
AITKEN, HENRY, Darroch, Falkirk, N.B.
ANDERSON, SAMUEL, Academy Place, Airdrie, N.B.

BAXTER, ANDREW, Whifflet Station, Coatbridge, N.B.
BEVERIDGE, JOHN, Kelty Colliery, Blairadam, Kinross-shire.
BROWN, M. WALTON, 5, Lambton Road, Newcastle-upon-Tyne.
BRYSON, D. R., 138, Hope Street, Glasgow.
BUCHANAN, Sir DAVID CARRICK, Drumpellier, Coatbridge, N.B.
BURNETT, SAMUEL, Plains, Airdrie, N.B.

CAMERON, WILLIAM, Finnie Street, Kilmarnock, N.B.
CAMPBELL, COLIN, Carron Works, Falkirk, N.B.
CARMICHAEL, ROBERT, Pentland Works, Loanhead, Midlothian.
CHAMBERS, JOHN.
CLARK, JOHN, Arniston Colliery, Gorebridge, R.S.O., Midlothian.
CRANSTON, DAVID, Woodend Colliery, Armadale, Linlithgowshire.

DANKS, HENRY, Green Colliery, Wishaw, N.B.
DODDS, JOSEPH, Crofthead Colliery, Fauldhouse, Linlithgowshire.
DUNCAN, JOHN, Daldowie Colliery, Broomhouse, Glasgow.

ELLIS, WILLIAM, Seafield Works, Bathgate, N.B.

FERGUSON, DAVID, 115, Buccleuch Street, Glasgow.
FERGUSON, DUNCAN, Lochore and Capeldrae Collieries, Lochgelly, R.S.O Fifeshire.
FERGUSON, WILLIAM, Byrehill Row, Kilwinning, R.S.O., Ayrshire.
FRISKIN, GEORGE, Inkermann Works, Paisley, N.B.

GALLOWAY, JAMES M., Trabboch Colliery, Drongan, Ayr, N.B.
GARDNER, JOHN, 9A, Hopetoun Street, Bathgate, N.B.
GIBB, WALTER, Ferniegair Colliery, Hamilton, N.B.
GOODWIN, GEORGE, Prestongrange Colliery, Prestonpans.

HARROWER, D. K., Knowepark, Bo'ness, R.S.O., Linlithgowshire.
HENDRIE, JAMES, Lassodie Mill Colliery, Kelty, Fife.
HERD, SAMUEL, Balgonie, Markinch, N.B.
*HOGG, WILLIAM, Carnmoor Cottage, Forth, Lanark, N.B.
HOOD, ARCHIBALD, 6, Bute Crescent, Cardiff.
HYSLOP, WILLIAM, Bank Colliery, New Cumnock, R.S.O., Ayrshire.

KELSO, JOHN, High Blantyre Road, Burnbank, Hamilton, N.B.
KESSON, ANDREW, Clydebank House, Bothwell, Glasgow.
KING, PETER, Darngavil, Airdrie, N.B.

*LANDALE, Dr. DAVID, The Binn, Burntisland, N.B.
LOGAN, WILLIAM, Almond House, Linlithgow, N.B.
LOVE, JOHN, Lynedoch Cottage, Loanhead, N.B.

M'CANN, EDWARD, 9, Westpans, Musselburgh, N.B.
M'CULLOCH, JOHN, Jawcraig Colliery, Slamannan, Stirlingshire.
M'CULLOCH, JOHN, Loganlea Colliery, West-Calder, R.S.O., Midlothian.
M'DONALD, JOHN, Greenhill Colliery, Holytown, R.S.O., Lanarkshire.
M'GEE, JOHN, 146, Almada Street, Hamilton, N.B.
M'GILL, JAMES, Bog House, Hollandbush, Bonnybridge, R S.O., Stirlingshire.
M'KENZIE, WILLIAM, Janebank, Loanhead, N.B.
M'KILLOP, JAMES, Polmont Park, Polmont, Stirlingshire.
M'KINNELL, WILLIAM, 30, South Grove Road, Sheffield.
MAXWELL, JAMES, Limerigg Cottage, Slamannan, Stirlingshire.
MAXWELL, PETER, Redding Muirhead, Polmont Station, Stirlingshire.
MORROW, SAMUEL, Palacecraig, Airdrie, N.B.

NASMYTH, A., Donibristle Colliery, Crossgates, Fife.
NASMYTH, J. A., Donibristle Colliery, Crossgates, Fife.
NEILSON, BENJAMIN, Prestongrange Coal Co., Prestonpans, R.S.O., Haddingtonshire.
NIMMO, THOMAS, 6, Melqurd Terrace, Edinburgh.

RANKIN, GEORGE, Victoria Works, Nitshill, Hurlet, Glasgow.
RENNIE, WILSON, Gateside Colliery, Cambuslang, Glasgow.
ROBERTSON, DAVID, 135, Waterloo Street, Glasgow.
ROBERTSON, Dr. J. R. M., Linton, Pitt Street, Wilson's Point, Sydney, New South Wales.
ROBERTSON, JOHN, Jun., 12, St. Vincent Place, Glasgow.
ROBERTSON, ROBERT, Jun., 1, Union Place, Rutherglen, Glasgow.
RUSSELL, ARCHIBALD, Jun., Avongrange, Hamilton, N.B.
RUSSELL, JOSEPH, Newton Colliery, Newton, Glasgow.
RUSSELL, P. B., Newfield, Hamilton, N.B.
RUSSELL, ROBERT, Coltness Iron Works, Newmains, R.S.O., Lanarkshire

Scott, William, 56, Braid Road, Edinburgh.
Sharp, Robert, Coatbridge, N.B.
Smith, Eustace, Jun., St. Lawrence Ropery, Newcastle-upon-Tyne.
Smith, John, Cannock Lodge Colliery, Bloxwich, Staffordshire.
Smith, John, Rosehall Colliery, Coatbridge, N.B.
Sparrow, Wm. B., 39, Clydesdale, Wishaw, N.B.
Stirling, John, Bonnybridge, Stirlingshire.
Strachan, Peter, 94, Aitchieson Street, Airdrie, N.B.

Twaddle, William, Ferniegair, Hamilton, N.B.

Waddell, Alexander W., Glenburn, Uddingston, Glasgow.
Wardrope, James, Fordell Colliery, Crossgates, Fife.
Weir, Thomas D., Ferro Carril Central de Venezuela, Caracas, Venezuela.
White, Andrew, Ormiston Colliery, Ormiston, Haddingtonshire.
White, William, 46, Bothwell Square, Bothwell, N.B.
Wylie, John, Clifton Iron Works, Coatbridge, N.B.

Young, William, 204, Stobcross Street, Glasgow.

TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT THE FIRTH COLLEGE, SHEFFIELD, FEBRUARY 19TH, 1896.

MR. G. A. MITCHELL, PRESIDENT, IN THE CHAIR.

Mr. GEORGE LEWIS (Derby) said that he wished, on behalf of the Chesterfield and Midland Counties Institution of Engineers, to say that they were very happy to see so many members present from various parts of the country. They hoped that the meeting would be of general interest to the majority of them, and he thought that there was every probability of valuable papers being read.

The PRESIDENT, on behalf of the members, said that he thanked Mr. Lewis for the kind welcome that he had extended to them on behalf of the members of the Chesterfield and Midland Counties Institution of Engineers.

PRIZES.

The SECRETARY announced that the Council had awarded prizes of books to the writers of papers which had been published in volumes viii. and ix. of the *Transactions*:—

"The Magnetic Survey of Great Britain." By Prof. A. W. Rücker.
"Investigations on the Composition, Occurrence, and Properties of Black-damp." By Messrs. John Haldane and W. N. Atkinson.
"Canals." By Mr. Lionel B. Wells.
"Electric Transmission of Power." By Mr. Alexander Siemens.

A paper by Mr. Alfred Siersch on "Photography in the Technology of Explosives" was read:—

PHOTOGRAPHY IN THE TECHNOLOGY OF EXPLOSIVES.

By ALFRED SIERSCH.

In consequence of the frequent occurrence of accidents in coal-mines of recent years, various countries have increased the strictness of existing regulations relating to blasting and inspection, and have also delegated to commissions the task of elucidating the causes and best methods of preventing explosions in fiery mines. Experts have, however, been engaged for a considerable period in attempting to devise, from the results of experiments, measures suited for increasing the safety of mining operations.

Photography has already been of great service to science, but up to the present has only found limited employment in the technology of explosives.

The flash resulting from the ignition of explosives is well known to exhibit variations in intensity, etc., but observers have been content to recognize the fact without bestowing further attention thereupon ; indeed, it is not easy to determine, in the case of a flash lasting only a small fraction of a second, whether it is comparatively large or small, there being many external circumstances, such as the distance of the observer from the spot where the explosion occurs, the nature and size of the charge, the degree of darkness, fog, etc., which influence the observation to a considerable extent. The writer agrees with those experts who are of opinion that the safety of an explosive appears to increase in proportion as the flash decreases, and in order to measure the latter and to be able to determine its nature and intensity, he has endeavoured, by means of photographs of the various phenomena, to collect material for an effective method of comparison. The photographic plates obtained showed such surprising results that he has no hesitation in stating that photography is calculated to be of great service in the technology of explosives. Photography affords a better means of determining the nature and manner of the decomposition of the explosive than either analysis or ignition-tests, excluding, moreover—when carefully employed —all risk of error. Photography shows undoubtedly that the different explosives give different plates, and that each variety is characterized

by its distinctive flash, this being especially manifested by the photographic pictures obtained in the case of two different explosives suspended one above the other and ignited simultaneously.

This fact by itself indicates a certain regularity of decomposition and invites one to a closer investigation. To the expert, it foreshadows the possibility of obtaining a clearer insight into the value of an explosive material, it being important to him to ascertain in the quickest manner the action of the individual constituents, the correctness of the method of preparation, and the influence of the different mixtures. To the mining engineer it will afford a ready means for convincing himself in the simplest manner of the relative security of the explosives employed, as few collieries are provided with an experimental gallery suitable for making experiments with explosives, and, moreover, such tests occupy much more time than is required for taking a photograph.

We are now, undoubtedly, only in the early stages of the new method of testing, but it is one that, as in other instances, will certainly undergo important developments and extensions in a comparatively short time.

As soon as the experiments now progressing in an experimental gallery have confirmed the accuracy of the writer's researches, the methods of testing explosives, now varying in individual experiments, will attain the uniformity that their importance requires.

On the basis of the investigations made up to the present time, the following conclusions may be considered as proved :—

a. The flashes produced by the ignition of various explosives are not identical : the smaller the flash the greater the relative security of the explosive. Figs. 1 to 16 (Plates I. and II.) are pictures exhibiting the results of igniting 3·53 ounces (100 grammes) of each of the following explosives in freely suspended cartridges :—

Fig. 1.—Nitro-glycerine.
„ 2.—Gun-cotton.
„ 3.—Nitro-starch.
„ 4.—Hellhoffit.
„ 5.—Blasting-gelatine.
„ 6.—Gelatine-dynamit I.
„ 7.— „ „ II.
„ 8.—Guhr-dynamit.
Fig. 9.—Roburit.
„ 10.—Carbonit.
„ 11.—Wetter-dynamit.
„ 12.—Westfalit.
„ 13.—Dahmenit.
„ 14.—Grisoutine.
„ 15.—Grisoutit.
„ 16.—Progressit.

Figs. 17 to 22 (Plate III.) show the flashes of blown-out shots of 100 grammes each of gelatine-dynamit I. stemmed with wet paper (Fig. 17), guhr-dynamit (Fig. 18), roburit (Fig. 19), antigrisou (Fig. 20), wetter-dynamit (Fig. 21), and progressit (Fig. 22).

Bergassessor Winkhaus states* that the following minimum charges sufficed to ignite mixtures containing 6·5 to 7 per cent. of pit-gas :—

	Ounces.		Grammes.
Gelatine-dynamit	1·76	...	50
Guhr-dynamit	2·05	...	58
Roburit	5·43	...	154
Westfalit	8·85	...	251
Dahmenit	8·85	...	251
Progressit	19·40	...	550

A casual inspection of the flash-pictures from these explosives will confirm what has been advanced under this section.

b. Other conditions being equal, each explosive gives a similar flash. The proof of this statement is afforded by the views of the flashes of freely suspended and simultaneously ignited double cartridges of 3·53 ounces (100 grammes) each of : gelatine-dynamit I., Fig. 23 (Plate IV.), roburit (Fig 24), wetter-dynamit (Fig. 25), and progressit (Fig. 26).

In order to ensure the safety of the camera, the double cartridges of gelatine-dynamit I. were exploded further distant than the others, which accounts for the picture being smaller than that in Fig. 6 (Plate II.). Between the roburit and wetter-dynamit cartridges a luminous zone of glowing gases is distinguishable (Figs. 24 and 25, Plate IV.).

c. The shape and dimensions of the flashes afford a clue to the eventual security of the explosives. Figs. 27 and 28 (Plate V.) show the flashes from 3·53 ounces (100 grammes) of guhr-dynamit in a caoutchouc envelope or water-cartridge, and 3·53 ounces (100 grammes) of guhr-dynamit under water (in a glass-beaker). Also a blown-out shot of 3·53 ounces (100 grammes) of gelatine-dynamit (Fig. 29, Plate V.) with moist paper stemming. Comparison of these pictures with Figs. 6 and 8 (Plate II.) confirms beyond contradiction the well-known fact that both by the water-cartridge and water-tamping, even highly dispersive explosives can be rendered safe. This is also the case with moss-tamping, as the views taken at the instance of Mr. Franz Brzezowski have shown.

d. Under otherwise identical conditions, the degree of security of an explosive decreases as the diameter of the cartridge (and the consequent size of the flash) is increased. Fig. 30 (Plate IV.) shows the flash given by 10·58 ounces (300 grammes) of progressit, in a cartridge 1·38 inches (35 millimetres) in diameter, and Fig. 31 that of 10·58 ounces (300 grammes) of the same explosive in a cartridge 1·97 inches (50 millimetres) in diameter.

e. The flash from an explosive varies—other circumstances being equal—with the density. This statement permits of conclusions being

* *Trans. Fed. Inst.*, vol. ix., page 263.

drawn respecting the greater or smaller explosibility of a blasting material. Figs. 32 and 33 (Plate IV.) display the flashes from 3·53 ounces (100 grammes) each of antigrisou of 1·20 and 0·90 densities respectively.

f. It is possible, by various admixtures, to increase or diminish the flash, the relative security of the particular explosive being correspondingly increased or diminished. Thus 3·53 ounces (100 grammes) of the following explosives gave the pictures indicated :—

Roburit, with admixture	Fig. 34, Plate V.
„ alone	„ 9, „ I.
Grisoutine, with admixture	„ 35, „ V.
„ alone	„ 14, „ II.

g. An increase in the length of the unstemmed portion of the bore-hole decreases—under otherwise equal conditions—the security of the blown-out shot. This observation has been already recorded by other investigators, and is now confirmed by the aid of photography. Fig. 36 (Plate V.) shows the result of the ignition of 3·53 ounces (100 grammes) of gelatine-dynamit I., with an unstemmed length of 17·72 inches (45 centimetres) borehole, and Fig. 37 the same explosive and charge with an unstemmed length of 5·51 inches (14 centimetres). The first experiment was made at the suggestion of Mr. Fr. Brzezowski.

h. The size of the flame increases with the weight of the charge of explosive. This statement is confirmed by experiments with blown-out shots containing 3·53 ounces (100 grammes), 7·05 ounces (200 grammes), and 10·58 ounces (300 grammes), and views of the results are shown in Figs. 38, 39, and 40 (Plate VI.) respectively.

i. The well-known fact that explosives with a nitrate-of-ammonium basis become safer in the presence of fire-damp in proportion as their carbon constituents decrease is exemplified by Figs. 41 to 44 (Plate VI.). The smallest flash was given by an explosive containing 6 per cent., and the largest by one having 18 per cent. of the same carbon compound in association with nitrate of ammonium. The intermediate pictures are from explosives containing 8 and 12 per cent. of the same carbon compound.

k. Even when the blasting-cartridge is situated in an inconvenient position with reference to the sensitized plate the flashes from so-called safety-explosives are smaller than those from high explosives. Figs. 45 to 48 (Plate VI.) show the flashes from freely suspended blasting-cartridges of gelatine-dynamit I., roburit, wetter-dynamit, and progressit, with the mouth of the cartridge turned away from the sensitized plate.

The remark "under otherwise identical conditions" implies that the composition and preparation of the explosive is identical, *i.e.*, the

quantity of explosive, length, diameter, density, and cover of the cartridge, and the strength of the initial detonation require adjusting with the greatest care. The camera must, of course, be placed at a constant distance from the spot where the explosion is produced, and the plates employed, whether lumière, eosin, cyanin, or any other kind, must be of the same degree of rapidity.

From the foregoing remarks, it appears that photography affords unusually great assistance in the determination of the nature and action of explosives, by enabling the relative degree of security to be quickly ascertained, and indicates to the technologist the manner (so far as composition is concerned) and method of preparing new explosives. It affords also an insight into the effect of various modes of stemming, and is, therefore, an aid that should certainly not be underestimated in the technology of explosives.

Mr. A. H. Stokes (H.M. Inspector of Mines, Derby) asked whether the author could supply the members with particulars as to how these beautiful photographs had been taken? He would like to know what description of sensitized plates had been used for the purposes of the photographs, where the camera was placed, and other details of manipulation. The experiments on explosives made by a committee of the North of England Institute of Mining and Mechanical Engineers were interesting, but it would have been better if (instead of depending on the eyesight) they had obtained permanent photographic records, similar to the photographs exhibited by Mr. Siersch, as to whether flame was produced or not. He noticed that the flame produced by blasting-powder had not been recorded; it would have been interesting if Mr. Siersch could have given them a record. Mr. Siersch gave them the interesting fact that the water-cartridge was safe. He also made the curious statement that the degree of security of an explosive decreased as the diameter of the cartridge (and the consequent size of the flash) was increased. He (Mr. Stokes) would like to know whether any attempts had been made to photograph the flame of detonators, because with a very small cartridge the flame registered would probably not be the flame of the explosive but the flame of the detonator.

Mr. M. Deacon (Blackwell) said that the members had records of experiments with coal-dust and experiments to show the power of various explosives. These had helped the members to a considerable extent,

Fig. 3. Nitro-starch, 3·53 ounces

Fig. 7. Gelatine-Dynamit II, 3.53 ounces.

Fig. 9

quantity of explosive, length, diameter, density, and cover of the cartridge, and the strength of the initial detonation require adjusting with the greatest care. The camera must, of course, be placed at a constant distance from the spot where the explosion is produced, and the plates employed, whether lumière, eosin, cyanin, or any other kind, must be of the same degree of rapidity.

From the foregoing remarks, it appears that photography affords unusually great assistance in the determination of the nature and action of explosives, by enabling the relative degree of security to be quickly ascertained, and indicates to the technologist the manner (so far as composition is concerned) and method of preparing new explosives. It affords also an insight into the effect of various modes of stemming, and is, therefore, an aid that should certainly not be underestimated in the technology of explosives.

Mr. A. H. Stokes (H.M. Inspector of Mines, Derby) asked whether the author could supply the members with particulars as to how these beautiful photographs had been taken? He would like to know what description of sensitized plates had been used for the purposes of the photographs, where the camera was placed, and other details of manipulation. The experiments on explosives made by a committee of the North of England Institute of Mining and Mechanical Engineers were interesting, but it would have been better if (instead of depending on the eyesight) they had obtained permanent photographic records, similar to the photographs exhibited by Mr. Siersch, as to whether flame was produced or not. He noticed that the flame produced by blasting-powder had not been recorded; it would have been interesting if Mr. Siersch could have given them a record. Mr. Siersch gave them the interesting fact that the water-cartridge was safe. He also made the curious statement that the degree of security of an explosive decreased as the diameter of the cartridge (and the consequent size of the flash) was increased. He (Mr. Stokes) would like to know whether any attempts had been made to photograph the flame of detonators, because with a very small cartridge the flame registered would probably not be the flame of the explosive but the flame of the detonator.

Mr. M. Deacon (Blackwell) said that the members had records of experiments with coal-dust and experiments to show the power of various explosives. These had helped the members to a considerable extent,

Fig. 3. Nitro-starch, 3·53 ounces.

Fig. 7. Gelatine-Dynamit II, 3.53 ounces.

Fig. 9

Fig. 3. Nitro-starch, 3·53 ounces.

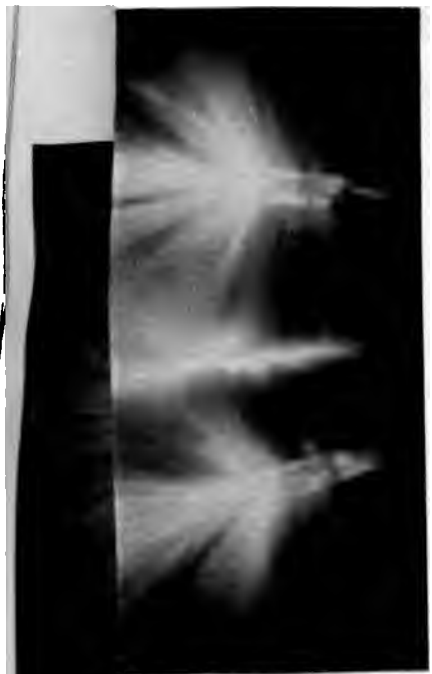
Fig. 7. Gelatine-Dynamit II, 3.53 ounces.

Fig. 18. Guhr-Dynamit, 3.53 ounces, blown-out shot.

Fig. 20

Fig. 18. Guhr-Dynamit, 3.53 ounces, blown-out shot.

Fig. 20



-Dynamit, two cartridges o
each, fired simultaneously.

, 10.58 ounces
.97 inches in
er.

Fig. 23. C

3.53 ounces
f 1.20.

Fig. 26. Progressit (5%), two cartridges of 3.53 ounces each, fired simultaneously.

Fig. 33. Antigrisou, 3.53 ounces, of a density of 0.90.

Fig. 2

Fig. unces
ker.
Chesterfield

Fig. 37. Gelatine-Dynamit I, 3.53. ounces with an unstemmed length of 5.51 inches, blown-out shot.

Fig. 35 Grisoutine with admixture 3.53 ounces.

Nitrate of Ammonium
of carbon compound.

Fig. 48. Progressit, back end of cartridge.

, back end of
ge.

Fig. 47. Wetter-Dynamit, back end of cartridge.

Fig. 45. Gelatine-Dynamit I, back end of cartridge.

but he would like to know whether, by means of photography, they could ascertain the relative intensities of the flames produced by various explosives.

Mr. ALFRED SIERSCH (Pressburg, Hungary) wrote that the photographs of the luminous phenomena resulting from the detonation of various explosives were taken on dark nights, in the following manner:—The suspended cartridge *I* (Fig. 49), which is intended to be detonated, having, as a rule, a diameter of 1·38 inches (35 millimetres), and a length varying between 3·94 and 5·12 inches (100 and 130 millimetres), is

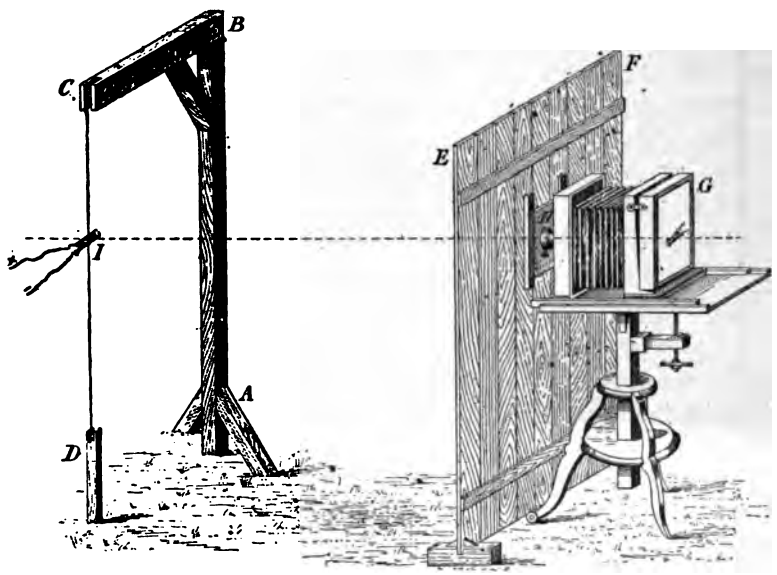


Fig. 49.

secured to a wooden framework *A B C*, by a copper wire *C D*, in such wise that the whole length of the illuminated cartridge is clearly seen in the camera. The electric detonator (No. 8), which has already been fixed in the cartridge, and contains 30·86 grains (2 grammes) of fulminate, is connected to the magneto-electric exploder, about 150 feet distant. In this way, the position of the cartridge remains unaltered.

The camera *G*, provided with a lens about 4½ inches (115 millimetres) in diameter, is placed 7·22 feet ($2\frac{1}{5}$ metres) distant from the suspended cartridge. It is protected by a strong wooden partition *E F*, wherein a hole is pierced for the lens; the latter is in turn shielded by a glass plate placed in front of it. These preparations being completed, the source of illumination is removed, the sensitive plate is placed in the camera, and the shot is fired.

In the case of blown-out shots, a cylindrical steel cannon is used, the dimensions of which are:—Height, 31·50 inches (800 millimetres); diameter, 21·65 inches (550 millimetres); the depth of the borehole being 18·11 inches (460 millimetres); and the diameter of the borehole, 2·16 inches (55 millimetres). The steel cannon is placed in a perpendicular position, and is sunk in the earth up to its topmost edge. In the course of these experiments, the camera is placed at a distance of 4·92 feet (1½ metres) from the bore of the cannon.

The views shown as successively smaller and smaller in Plates I. and II. may give rise to the supposition that where the flame-phenomena appear weaker, smaller cartridges were used. But such is not the case. The value of the experiments consists chiefly therein that photography furnishes undeniable proof that various explosives give rise to various flashes, while the same explosive gives rise to identical or very similar flashes.

In the paper the quantity of explosive detonated has been recorded in each case.

The writer may further remark that, in order to obtain useful and reliable images, the work must be done with minute care and attention; both the expert in explosives and the photographer must see that the prints are prepared in exactly the same way in all cases. The slightest alteration in the conduct of these experiments would lead to error, not to say failure.

In order to photograph the flame of a detonator, the camera should be brought very near to the last-named, as no image is obtained at such a distance as 7 feet (2⅓ metres).

He (Mr. Siersch) thanked the members of the Institution for the distinction accorded to him, and remained at the disposal of the members for further explanations. Blasting-powder had not been included within the scope of the researches, because he was unacquainted with its composition.

The CHAIRMAN, in adjourning the discussion, said that Mr. Siersch's photographs were very beautiful; he believed that considerable difficulties had been experienced in taking and printing them, and hoped that they could be reproduced in the *Transactions*. He moved that the thanks of the members be accorded to the author for his interesting paper.

The resolution was agreed to.

Prof. EDWARD HULL read the following paper on "The Eastern Limits of the Midland Coal-field":—

THE EASTERN LIMITS OF THE MIDLAND COAL-FIELD.

By Prof. EDWARD HULL, LL.D., F.R.S., F.G.S.

The writer has been invited by the Council to read a paper at this meeting on the subject of "The Eastern Limits of the Midland Coal-field." In order to approach the subject it is necessary first to determine what is the meaning and extent of the term "Midland Coal-field."* It seems to be a collective term; not intended to designate a single coal-field, but a group, in which may be included those of North and South Staffordshire, Leicestershire, and Warwickshire. These four visible coal-fields lie in the centre of England, and for the most part south of the river Trent, and are isolated from the great coal-bearing tracts of the North of England, either by considerable areas of Triassic strata, or (as in the case of the North Staffordshire coal-field) by the uprising of the Lower Carboniferous rocks. For the purpose of this enquiry, however, it is only necessary to deal with the Leicestershire and Warwickshire coal-tracts, which may be regarded as the outward and visible signs of extensive sheets of concealed Coal-measures connecting them, to a greater or less extent, with the more westerly coal-fields of North and South Staffordshire.

At first sight, when looked at by the aid of a geological map of England, the Leicestershire and Warwickshire coal-fields might be supposed to extend indefinitely under the Triassic and more recent Secondary strata which form the surface of East Anglia and the intervening district; and this, notwithstanding the ominous uprise of very old pre-Carboniferous rocks in the centre of Leicestershire, including Charnwood Forest. At one time these ancient rocks, concerning whose geological age there is still much uncertainty, were regarded as having formed an island round which the Coal-measures were deposited on all sides; in which case the coal-strata might be expected to occur to the east and north of the island, as well as to the west and south of it; extending, it might be, indefinitely eastwards under the tract of the Wash and its borders into East Anglia. Would that it were so! for in such a case the concealed area of the Coal-

* The coal-fields of Nottinghamshire and Derbyshire, which are sometimes classed as "Midland," belong by their structure and relations to the Yorkshire and Durham coal-fields; the valley of the river Trent forms a good line of separation between the Midland and Northern systems.

measures would surpass in extent the actual area of this formation as visible at the surface, along with the adjoining tracts where this formation is known to underlie newer formations. The author regrets that recent investigations, supported by the information gained in boring operations under the district referred to, do not tend to confirm this view.

The subject is one of very great importance, though not as regards the immediate future, since we have really more available coal than we can well dispose of at the present time. But it is not the less incumbent

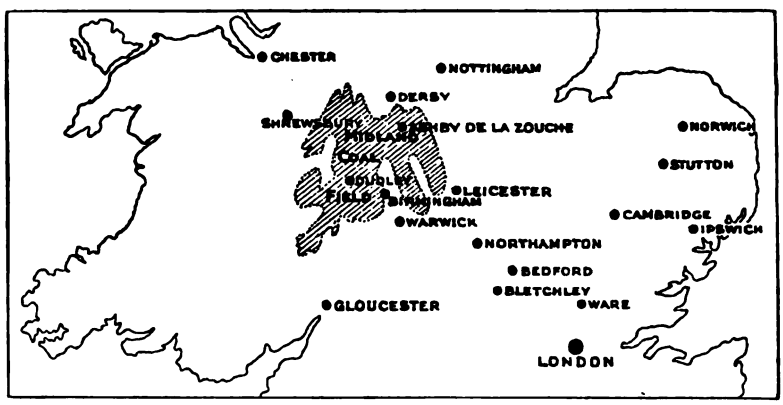


Fig. 1.—Map showing the Extent of the Midland Coal-field: the Shaded Portion represents the Area of the Coal-measures both at the Surface and concealed below more Recent Formations.

upon us to look ahead in order to get a fair idea of our possible coal-resources, for it is absolutely certain that we are using up those resources very rapidly: that is to say, we are drawing upon our capital of mineral fuel.

Historical Review.—Before entering directly upon the points under discussion, it is desirable to make a brief historical review of the labours of those geologists who have from time to time investigated this subject. Ever since the year 1866, when Sir Roderick I. Murchison delivered his address at the meeting of the British Association at Nottingham on "The Parts of England and Wales in which Coal may, and may not, be looked for beyond the known Coal-fields,"* the subject of the eastward and southward extension of these fields has occupied the attention of geologists and mining engineers. In that address the author expressed his opinion against the probable extension of the Coal-measures under the Eastern Counties. This was a very sagacious opinion, coming at the time it did, delivered by one who was so capable of drawing sound, general conclusions from geological data. A few years previously, however, the

* *Report of the British Association*, 1866, vol. xxxvi., pages 57 to 63.

late Prof. J. B. Jukes in his preface to the second edition of his "Memoir on the South Staffordshire Coal-field"* had clearly pointed out the evidence for inferring that a land-surface forming an island, or group of closely connected islands, composed of Silurian rocks occupied the region of the South Staffordshire coal-field and adjoining districts during the Lower Carboniferous period, owing to which neither the Mountain Limestone nor the Millstone Grit Series are represented in that part of England; and, he adds: "This land, however, must itself have been depressed either wholly or in part, while the Coal-measures were being deposited, and as it slowly sank beneath the water, sheet after sheet of Coal-measures extended over it, till perhaps the whole was finally buried under one widespread subaqueous Coal-measure plain."† It seems fairly clear from this quotation that Prof. Jukes entertained the idea that coal-strata may have been deposited beyond, that is, to the east of "the group of islands."

As time went on, however, and investigation proceeded, our ideas became expanded; so that in the memoir on "The Triassic and Permian Rocks of the Midland Counties of England,"‡ published ten years after Prof. Jukes' Memoir above quoted, the author ventured to state his opinion that this supposed chain of islands was in reality the margin of a ridge of ancient Palæozoic rocks which separated the Carboniferous areas of the Midland Counties and Salop from those of South Wales, the Forest of Dean, Somersetshire, and possible concealed coal-troughs of the South of England. He regarded this, which he termed "The central barrier of land," as never having been wholly submerged or covered by Coal-measures, and considered it as extending into and embracing the Eastern Counties, as suggested by Sir Roderick I. Murchison.§ Westwards, this barrier was considered to extend through Shropshire into North Wales, and thus to have formed a ridge completely severing the coal-districts of the Midlands and North of England and Wales from those occupying the southern parts.

This more extended view regarding the physical importance of those ancient rock-masses of Leicestershire, Warwickshire, and Worcestershire which thrust themselves through the nearly horizontal strata of the Triassic period, like islands bordering the mainland, must now be further extended, in the author's opinion, to considering them in reality the borders of the mainland itself. In other words, the eastern parts of Leicestershire

* *Memoirs of the Geological Survey*, 1859. † *Ibid.*, Preface, page 13.

‡ *Memoirs of the Geological Survey*, 1869.

§ A little map showing the position of this Palæozoic barrier with the original Coal-measure areas is given in the *Coal-fields of Great Britain*, fourth edition, page 520.

and Warwickshire, and the adjoining tracts extending into East Anglia, which are covered by newer Secondary formations, are underlain, not by Coal-measures, but by rocks of a more ancient geological age, which remained unsubmerged in Carboniferous, Permian, and Triassic times.*

Having thus, in general terms, stated the position of the question before us as it appears at the present time, the author will now give some details regarding actual investigations by borings which go to bear out the views here expressed. These will, of course, refer to the tract immediately adjoining the Midland coal-fields themselves, and extending into the east of England. We shall begin with Leicestershire.

Leicestershire.—It had always been hoped—the writer might say expected—that a considerable reserve of coal would be found under the Triassic strata lying to the south and west of the Leicestershire coal-fields. Collieries have been opened to work the main coal-seam under the New Red Sandstone at Overseal and Netherseal in this direction. But the condition of this important seam, interrupted and much spoiled as it is by bands of sandstone, appears to indicate an approach to the original margin of the Carboniferous basin. The proximity of this marginal land, formed of much older rocks, has, the writer regrets to say, been recently determined by direct borings undertaken by the Netherseal Colliery Company at a distance of about 1 mile south of the existing colliery, which gave the following generalized results:—†

	Feet.
1. New Red Sandstone, with pebbles of quartz	262
2. Coal-measures above the main seam	514
3. Older Palæozoic rocks	19
Total	795

The older Palæozoic rocks (No. 3) consist of reddish, purple, and grey grit, sandstone, and micaceous quartzite, destitute of fossils, thus contrasting with the Coal-measures above (No. 2), which are full of plant-remains. A second boring, put down about 1 mile further to the south-east, gave similar results, when reddish vitreous quartzite, slightly micaceous, was penetrated at a depth of 760 feet. This rock bore a strong resemblance to the Hartshill stone of Warwickshire. On examining these cores the writer came to the conclusion that they belong to the Cambrian system: a conclusion in which Prof. Lapworth concurs. ‡ It is clear, therefore,

* This the writer endeavoured to represent in the "Ideal Transverse Section of England," *Coal-fields of Great Britain*, fourth edition, page 533.

† *Trans. Fed. Inst.*, vol. viii., page 90.

‡ *Report of the British Association*, 1893, pages 745-6.

that a ridge of these very old rocks here replaces the Middle and Lower Coal-measures, together with all the Lower Carboniferous strata, and causes the productive Coal-measures of the Leicestershire coal-field to terminate towards the south-west, just as the old rocks of Charnwood Forest form their limit in the opposite direction.

Between this concealed ridge and the visible Charnwood Forest rocks there lies a deep bay of Coal-measures concealed by Triassic strata, in which the Ibstock and Bagworth collieries are located; and the boring through the New Red Marl near Desford, about 6 miles west of Leicester, which is said to have reached Coal-measures, shows that this bay stretches far towards the south. Further east, however, the bosses of syenite of Mount Sorrel, Barrow Hill, Stony Stanton, and Sapcote, rising above the plain of the New Red marl, appear to be clear indications that the centre and east of Leicestershire are underlain by rocks much older than the Carboniferous.

Warwickshire.—The eastern margin of the Warwickshire coal-field is clearly indicated by the Lower Silurian (or Upper Cambrian) beds, consisting of the Hartshill quartzite and Stockingford shales, which rise from below the Coal-measures, from Atherstone on the north to the neighbourhood of Bedworth on the south, where the Coal-measures pass below the New Red marl. Coal is now worked below this formation as far as Wyken, and may extend some distance yet further south. Some years ago the writer was under the impression that Coal-measures might set in to the east of the ridge of Hartshill; but further consideration, fortified by further researches, now leads him to abandon this view, and to consider it as improbable that coal will be found under the tract around Hinckley under the Triassic strata. Further borings are desirable in order to determine this point with certainty.

Northamptonshire.—The borings which have been put down in this county have been undertaken chiefly in search of water. But in at least two cases the Palæozoic rocks have been proved beneath those of Mesozoic age, and, therefore, throw light on the structure of the county at considerable depths. These the writer will further describe :—

1. At Orton, a village about 10 miles north of Northampton, a boring has been put down commencing in the Lias, and after passing through the New Red Marl entered rocks consisting of hard grits and slates. On examining specimens sent to the writer by the late Mr. Samuel Sharp of Great Harrowden Hall in the year 1881, the author came to the conclusion that they were of Lower Silurian or Cambrian age.

The author may here observe that in the absence of fossils there is often great difficulty in determining the exact geological age of some cores. Hard slates and grits of various colours may be derived from various formations, from the Devonian downwards. In the case of the Midland counties of England Devonian rocks are absent, and as Upper Silurian rocks are generally recognizable by their fossils, we are pretty safe when we refer "hard grits and slates" either to Lower Silurian (Ordovician) or Cambrian age, as the writer has done in the case of the specimens from Orton. *

2. Near the town of Northampton there have been several borings in which the rocks reached are, according to Mr. Whitaker, older than the Carboniferous. Here the Trias (Red Marl) is thin, and in one place absent.† In one of the borings, however, Carboniferous Limestone with characteristic fossils, determined by Mr. Etheridge, was passed through at a depth of 890 feet.‡ Mr. Etheridge suggests that there is here an indication that in the tract between Northampton and the exposed coal-field of Warwickshire there may be "an extended coal-field." This the writer much doubts, for although the presence of Carboniferous Limestone at Northampton presupposes the former existence of Coal-measures, he considers that, owing to an extended period of denudation previous to Triassic times, the Upper Carboniferous beds have been swept away in the tract referred to. This, however, is a point that can only be absolutely settled by direct boring experiments, which are much to be desired.

Buckinghamshire, etc.—Somewhat further south, at Bletchley, a boring was made a few years since in search of water by the London and North-Western Railway Company, and a rock was reached beneath the Lias, a specimen of which the writer had an opportunity of examining. It proved to be a felsite, and seems to indicate the presence of old rocks invaded by trap. Other borings at Ware, Cheshunt, and Culford have proved that Upper Silurian beds lie beneath the Mesozoic strata. § These localities are, however, too far removed from the district of the Midland coal-fields to be further noticed here. They are rather connected with the structure of the region of the London Basin, and are only interesting to us as confirming the absence of coal under this part of England.

* For such rocks, the term "Cambro-Silurian" might be usefully employed.

† Presidential Address, Section C, *Report of the British Association*, 1895, vol. lxv., page 671.

‡ Presidential Address, *Quarterly Journal of the Geological Society*, London, 1881, vol. xxxvii., *Proceedings*, page 231.

§ Mr. Etheridge, *Ibid.*, vol. xxxvii., *Proceedings*, page 230. Mr. Whitaker supposes the rock from which the specimen at Bletchley came to have been a boulder, but this is open to much doubt.

Suffolk.—A most important boring has recently been carried out under the east of England by the Eastern Counties' Coal-boring Association. To the subscribers to this association it must needs be disappointing; but it is of great interest to geologists as going very far towards settling the question regarding the presence or absence of coal under East Anglia. The position of the experiment is the valley below Crepping Hall, near Stutton, close to the borders of Norfolk and Suffolk, and the following is a generalized section of the boring:— *

BORING AT STUTTON, SUFFOLK.

	Feet.
1. Gravel, etc.	16
2. Tertiary strata	54
3. Upper, Middle, and Lower Chalk	874
4. Gault clay	50
5. Palæozoic grits and slates	534
Total	1,528

The Palæozoic rock (No. 5), which has a high dip southwards, consists of grey slates, resting on purple and dark grey grits and slates, much crushed, fissured and destitute of fossils; † the specimens when tested did not effervesce with acid, showing that calcareous rocks were absent. The absence of fossils is much to be regretted; but to the writer the rock appears undoubtedly to be pre-Carboniferous; and, in fact, to belong to that group of rocks of indeterminate age, which might be referred either to the Lower Silurian or Cambrian, of which we have examples at Orton and elsewhere. The evidence which we obtain from this boring tends to confirm the view of the absence of Coal-measures under East Anglia, certainly for a considerable area around Stutton; and if further borings are undertaken by the company they ought to be placed a considerable distance either to the north or south of the county-boundary between Norfolk and Suffolk. It ought to be mentioned, however, that slate, supposed to be Carboniferous, with *Posidonia* was reached some years ago below the Chalk at Harwich.

Further boring experiments in well-selected spots are certainly desirable, and may result in agreeable surprises; but as regards this point the writer does not profess to be sanguine.

South Staffordshire and Worcestershire.—It now only remains to deal with the question of the limits of the South Staffordshire coal-field

* For which the writer is indebted to Mr. Whitaker, who informs him that the direction of the dip of the Palæozoic rocks is generally southward, not strictly south.

† The cores were shown to the writer by Mr. W. W. Watts, F.G.S., at the Museum of Practical Geology in December, 1895. See Mr. Whitaker's Presidential address to Section C, *Report of the British Association*, 1895, vol. lxv., page 666.

towards the east and south. As Prof. Jukes has shown, a Silurian land-surface, formed of strata slightly rising towards the east, occupied originally what is now the southern portion of this area.* The uprise of the Silurian quartzite of the Lickey Hills through the Permian beds proclaims the limit of the Carboniferous strata in a southerly direction. But, considerably to the north of this, the southern limits of the productive Coal-measures have been proved by the shafts which, some years since, were put down by Messrs. Dawes at Wassel Grove and Manor Farm, about 2 miles south of Halesowen. Here the thick coal-seam was only represented by "fragments of carbonized plants mixed with sandstone and fragments of Silurian rock; while, a little lower, the shales of the Upper Silurian formation with *Pterygotus* were passed through for some considerable depth."† This experiment, so costly and disappointing to the enterprising owners of the shafts, settles the question of the southern limit of the thick coal-seam, and proves that it does not extend much (if at all) beyond the margin of the Permian beds, where they sweep from west to east across the Coal-measures a little north of the Clent hills (Fig. 2).

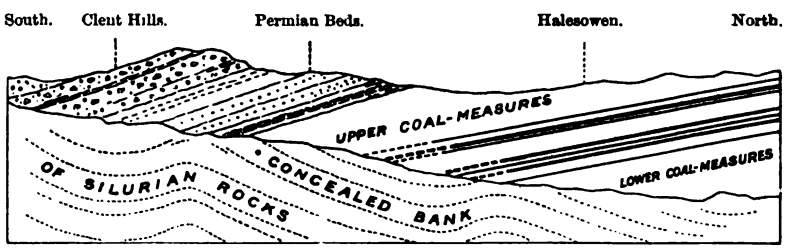


Fig. 2.—Transverse Section through Southern Portion of the South Staffordshire Coal-field, indicating the manner in which the Coal-Measures and overlying Permian Beds terminate towards the South in a Concealed Bank of Silurian Rocks.

On the other hand, the successful experiment to prove the thick coal-seam at Sandwell Park near Birmingham under the Permian beds may be regarded as a set-off to the failure at Wassel Grove, and shows that the Silurian ridge keeps well to the east of this spot. In fact, it seems probable that the limit of the productive Coal-measures with the thick coal-seam passes in a north and south direction under the New Red Sandstone of Birmingham. This ridge curving round from east to north probably divides, to some extent, the productive Coal-measures of Warwickshire from those of South Staffordshire, and ranges northwards

* *Memoir on the South Staffordshire Coal-field*, second edition, page 134.

† Sir A. C. Ramsay, *Report of the Royal Coal Commission*, 1871, vol. i., page 120. An account of this experiment was given by Mr. Henry Johnson at a meeting of the Mine Agents' Association, 1868.

in the direction of Barr Beacon; but new experiments, by boring or otherwise, are much to be desired, in order to define more accurately the extent of this concealed barrier of Silurian rocks.*

In conclusion, it will be inferred from the evidence before us that the old Cambro-Silurian rocks formed a ridge trending from Salop and Worcestershire eastwards into the eastern parts of the counties of Warwick and Leicester, which was very irregular in its outline, and sent out ridges or spurs, in a northerly direction separated by intervening bays (Fig. 1). Against the shelving sides of these ridges the Coal-measures were deposited, filling up the bays as the region gradually subsided under the Carboniferous waters, in consequence of which the Upper Coal-measures cover a more extended area than the productive Middle beds, and these than the Lower Carboniferous strata, which are altogether absent in South Staffordshire and Warwickshire.

The writer has been encouraged by a well-known geologist and former colleague to "hammer away at the process of extending the coal-areas eastward." He fears the result of his hammering has not been, as in the case of a piece of beaten gold, to extend its surface, but rather to cause it to assume smaller dimensions.

Mr. Wm. Cochrane (Newcastle-upon-Tyne) remarked that Prof. Hull was of opinion that there had been a quiet deposition of Carboniferous measures between the promontories formed by the jutting out of the Silurian mountainous districts. If that was so, how did it happen, in the Sedgeley district in the neighbourhood of Dudley, that the thick coal-seam was almost vertical, or banked up against the well-known Silurian rocks forming Dudley Castle? He had also found the Coal-measures lying in an inverted position in the Dudley district, and that was a continuous seam; he could not understand how it could have been formed in the quiet manner described by Prof. Hull. It seemed to him that the Silurian limestone had been forced up by volcanic action, and that the thick coal-seam had not been deposited on the sides of the Silurian mountainous district, but had been lifted

* That this Silurian ridge occurs to the east of the Sandwell Park and Hamstead collieries may be inferred from the observations of Mr. H. W. Hughes and Mr. F. G. Meachem, *Trans. Fed. Inst.*, vol. ix., page 256.

up to this great angle. He appreciated the completeness of the investigations made by Prof. Hull, as they had put the position with respect to the Silurian districts in a fuller light.

Mr. VIVIAN said that a very heavy dip to the south-west at an angle of about 40 degrees had been proved in the Stutton bore-hole. It had been decided to put down a bore-hole at Weeley, a few miles north-west of Clacton-on-the-Sea, it being anticipated that a possible coal-basin existed at that point.

Mr. G. J. BINNS (Netherseal) said that the main point which struck inhabitants of the Leicestershire coal-field in reading the very interesting paper by Prof. Hull, was one somewhat of surprise but still of gratification. They had previously been of the opinion that the district of Coal-measures extending from somewhere near Nottingham to the neighbourhood of Leeds constituted the Midland coal-field. The Coal Commission similarly named it, and, perhaps, the highest authority of all, Prof. Hull, defined the Midland coal-field as extending between the boundaries he had mentioned.* With regard to the section of the Netherseal bore-hole, he thought that the classification of the "Coal-measures above the main coal-seam" was given on evidence which was certainly, to his mind, inconclusive, but this was a detail and hardly worth mentioning, except that it might lead to a false impression. He agreed with Mr. Cochrane as to the arguments advanced to account for the disturbance of the coal-fields, and considered that close proximity to pre-Carboniferous land was insufficient to account for the phenomenon they unfortunately found in the collieries.

Mr. G. LEWIS (Derby) said that Prof. Hull had given the members a very valuable paper, but he must take exception to it in one sense. They had hitherto understood that Nottingham and Derbyshire belonged to the Midland coal-field. He thought that Prof. Hull should have given these a little place in his paper, and possibly it would then have interested some of them more had he done so. The great coal-field of the eastern district was a very important one, and whoever lived to see it would find it become most important, and the members would have been very glad indeed if Prof. Hull had made some remarks upon it.

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) observed that there was one part of Prof. Hull's paper which had surprised him, and that was the geography of the Midland coal-field. He certainly thought

* *Coal-fields of Great Britain*, page 245.

Derbyshire and Nottinghamshire were in that coal-field, and formed a great part of it. He would like to know whether Prof. Hull had any opinion on the chance there was of finding coal in Oxfordshire and Gloucestershire. Prof. Hull said that a "ridge curving round from east to north, probably divides to some extent the productive Coal-measures of Warwickshire from those of South Staffordshire."* Sir Roderick I. Murchison had told them that no coal would be found under Birmingham, but Sandwell Park and Hamstead collieries were conclusive proofs against that statement. He was surprised to find that there was a doubt as to the Staffordshire coal-field running into the Warwickshire coal-field. There was the Hamstead colliery-workings in the thick coal-seam within a short distance of the county of Warwick, and, moreover, the thick coal-seam extended towards Nuneaton. Sir Alf. Hickman's colliery at Haunchwood proved the extension of the Warwickshire coal-field towards Hamstead colliery. Mr. Newdigate had put down a bore-hole at Bedworth, and proved the coal-seam, and the Hockley Hall Colliery Company were sinking a shaft for the purpose of working the coal-seams extending to Whitacre Junction. These geographical details were not new information to some of the members, but he would condense it by stating that there was not a single fact against the belief that the Warwickshire coal-seams are the thick coal-seam of Staffordshire, which extends in one uniform field, and is not broken up. Both the east and west are approaching each other, and there are not many miles remaining unproved between them.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) said that Dr. Hull, in applying the term "Midland coal-field" to the area so excellently described in his paper, was following the outlines of the English coal-fields adopted by the Inspectors of Mines in the *Annual General Report upon the Mineral Industry* for the year 1894, in which the Midland coal-field was described as including the counties of Staffordshire, Worcestershire, Shropshire, Leicestershire, and Warwickshire. The coal-field of Yorkshire, Derbyshire, and Nottinghamshire, would, he thought, be more correctly described as the South Yorkshire or North Midland coal-field.

Dr. HULL, replying, hoped that those members who had taken part in the discussion would not consider him unreasonable or impolite if he did not go fully into their objections.

Mr. Cochrane asked why, if there were bays of Coal-measures and ridges of Silurian rocks and older rocks running up into the Midland coal-field, the thick coal-seam at Dudley was thrown into such a steep

* *Trans. Fed. Inst.*, vol. xi., page 16.

position? His reply was that the elevation of the thick coal-seam of Dudley and of the Silurian rocks had taken place subsequently; altogether at a later period than that of deposition. He was glad to hear that the Eastern Counties' Coal-boring Association had determined to put down another boring, and he thought they were wise in not putting it down, as they had proposed to do, in the strike of the Stutton bore-hole, but further to the north-and-west. He had been taken very much to task, and he was not surprised at it, by several members because he had confined the term "Midland coal-field" to the four coal-fields represented in the tinted portion of the map (Fig. 1). The question was one open to discussion. If they lived in London and said "we are going to Leeds," that implied "going to the north," and most people in the south of England when they talked of "the north" included Leeds, Manchester, and all those districts north of the districts shaded in his map; therefore he thought that he was justified in retaining the name Midland coal-field for the four coal-fields there united. Still, he was not going to quarrel with anyone who included Derbyshire. But geographically this would of course include the Yorkshire coal-field as well. It was really more a northern than a Midland coal-field, as Mr. Walton Brown had pointed out, and its eastern limits depended upon different physical conditions from those of the district whereof he had treated in his paper. Therefore, he was prepared to maintain that he was correct in that respect. In these days of compromise they might call the four coal-fields united in the map (Fig. 1) "the South Midland," and the "Yorkshire and Derbyshire," and "Nottinghamshire" district, "the North Midland;" and in that respect they might meet the views of the members present, including Mr. Binns, who took exception to the classification here adopted.

Mr. Stokes had taken a very natural exception to a part of his paper which indicated that it was intended to show that the Staffordshire and Warwickshire coal-fields are not physically connected. Some years ago, he was fully under the impression that they were not disconnected at all; and notwithstanding the new collieries which had been sunk near Birmingham, but which were all to the west of Birmingham and not directly under that tract. Before they came to the meridian of Birmingham they might probably come to an old ridge of rocks running up from the south. He hoped it might not prove so, but thought that geological evidence was in favour of that view. At the same time there was not an absolute and complete severance between the main coal-seams of South Staffordshire and of Warwickshire. Farther north, the Silurian rocks are represented on the map as terminating northwards, and beyond this there has been a physical connexion of the original coal-tract.

The CHAIRMAN had very great pleasure in moving a vote of thanks to Dr. Hull for his paper.

The motion was unanimously agreed to.

DISCUSSION ON MR. C. E. DE RANCE'S PAPER ON "THE DEPTH TO PRODUCTIVE COAL-MEASURES BETWEEN THE WARWICKSHIRE AND LANCASHIRE COAL-FIELDS."*

Prof. HULL said that he was gratified to know that Mr. De Rance concurred in his view regarding the existence of a concealed ridge of Lower Carboniferous rocks under the New Red Marl of the plain of Cheshire. This question he had fully discussed in a paper published by the Geological Society of London, in 1869.† As Mr. De Rance truly states, one of the main points of evidence of such a ridge (which is considered to separate the Coal-measures lying below the Triassic plain into two distinct coal-basins), was the difference in the characters of the Permian beds to the north and to the south of a line drawn across the plain somewhere in the parallel of Middlewich. Mr. De Rance seems to question whether there are any beds of truly Permian age south of this line, and seems inclined to regard the great series of red marls, sandstones, breccias, and conglomerates overlying the Coal-measures of the Midland districts and Shropshire, as referable to an uppermost Carboniferous stage. There is a great deal to be said for and against this view; but he (Prof. Hull) was not at present sufficiently advised to give his assent to so startling a proposition. Possibly this remarkable series might be the British representatives of the Permo-Carboniferous series of the United States of America, but the members must also recollect that, as Sir Roderick I. Murchison had long ago shown, they are the well-recognized representatives of the Lower Permian (*Rothe-todte-liegende*) series of Germany, which is highly unconformable to the Coal-measures of that country. Referring to the main question of Mr. De Rance's interesting paper, Prof. Hull was glad to see that he discourages experiments in search of coal in the plain of Cheshire. The thickness of the Triassic beds under that plain was undoubtedly enormous—a fact of which many geologists were aware, and which the boring put down by the Salt Union, near Northwich, had completely established. Prof. Hull finds that in the map which accompanies

* *Trans. Fed. Inst.*, vol. x., page 244.

† *Quarterly Journal*, vol. xxv., page 171.

his book on *The Coal-fields of Great Britain* (edition 1881), he had represented coal as "over 4,000 feet in depth" in the district south of Lymm; this the boring had verified. For, as Mr. De Rance shows, the depth to the top of the Coal-measures would be about 3,800 feet, and to this we must add several hundred feet (we really do not know how many) in order to reach the first workable coal-seam. The present abundance of coal, at a much less depth, will not justify coal-mining at depths over 4,000 feet from the surface. The evidence of the unconformity of the Upper to the Middle Coal-measures in South Staffordshire, as shown by Mr. Meachem to be the case at Hamstead colliery, was of much interest. In other districts, such as Shropshire, local unconformities had been observed and described by Prof. Prestwich and Mr. D. Jones. During the Coal-period oscillations of level had frequently occurred, which would give rise to breaks in the local stratification.

Mr. T. Crosbee Cantrill (Bewdley) noticed that Mr. De Rance had referred to Prof. Hull's remarks on the Wyre Forest coal-field, as recorded in the *Report of the Coal Commission* (1871). Since that time the knowledge of this coal-field has been considerably enlarged by several workers. Although there is apparently a complete absence of the Lower Limestone Shale, Mountain Limestone, and Yoredale rocks in the Wyre Forest district, yet so far from the Upper Coal-measures, with their few unimportant coal-seams, being the only Coal-measures in that coal-field, it is now certain on all grounds that an equal, if not larger, area consists of Middle measures, productive, in certain districts, *e.g.*, Harcott and Highley, of good "sweet" coal-seams, at the latter place about 5 feet in thickness. These coal-seams, however, rapidly thin out and deteriorate towards the south and south-east, as they approach the northern shore of the old barrier—here consisting of Old Red Sandstone as well as Silurian rocks—which entered the district from the direction of Wassel Grove and Halesowen in South Staffordshire. After the deposition of these Middle Coal-measures, considerable earth-movements went on; the coast-line of the old barrier retreated southwards, and large areas of the recently formed Middle Coal-measures were subjected to erosion. The result is that the Upper Coal-measures overlap the Middle Coal-measures and rest, in places, directly on the Old Red Sandstone and Silurian floor. Above these yellow Upper Coal-measures, with their thin pyritous coals and *Spirorbis*-limestone band, succeeded, with little more than small local breaks, the red so-called Permian-measures of Alveley and Enville, containing a *Spirorbis*-limestone band and a thin coal-seam at least 200 or 300 feet

above their base. These "red rocks" he (Mr. Cantrill) had elsewhere endeavoured to show are really of Upper Coal-measure age, and would be better described as Upper Coal-measure passage beds, *i.e.*, a series forming a gradual passage from the Coal-measures to true Permian and Triassic rocks. Or they might be called "Red Upper Coal-measures," as distinguished from the ordinary yellow Upper Coal-measures which underlie them.

At any rate, the great break, in Wyre Forest and Coalbrookdale, occurs, not between the so-called Permian and the Upper Coal-measures, but between the Upper and the Middle Coal-measures themselves.

The next great break is at the base of the Lower Bunter Sandstone (*f'*) of the Enville country. This formation, to the east of Bridgnorth, oversteps the various members of the so-called Permian measures. If this Lower Bunter should prove, as Mr. De Rance has hinted, to be the lower part of the true Permian, it is a further argument in support of the Coal-measure age of the so-called Permian measures which underlie it.

With regard to the presence and depth of profitable coal-seams to the east and north-east of the Wyre Forest coal-field, little can be stated with any certainty. But, so far as he could see, there is no reason to suppose that the Highley coal-seams do not continue towards South Staffordshire. However, boring, somewhere east of the river Severn and to the north of the Trimpley district, would alone settle this question.

Mr. DANIEL JONES (Shifnal) said that the members owed to Mr. De Rance a debt of gratitude for having collected together and brought before them the knowledge accumulated during the last thirty years as to the question of the depths to the productive Coal-measures laying between Warwickshire and Lancashire. Whilst he gives the most recent information about the Permian and Trias overlying the Coal-measures he should not leave the members so far behind with regard to present knowledge as to the Forest of Wyre coal-field, for he only quotes Prof. Hull's opinion expressed thirty years ago, "that in the Forest of Wyre and at Bridgnorth the Lower Carboniferous rocks are wholly absent, and the Upper Coal-measures with few and unimportant coal-seams rest on ancient rocks," etc., but the members do not know what is Prof. Hull's view to-day in the light of the evidence which has been brought forward on "The Structure of the Forest of Wyre Coal-field,"* and we know that coal-seams of Middle Coal-measures age are being worked on a fairly large scale at the Highley colliery, near Kinlet. In his (Mr. Jones') paper upon this subject read before the South Staffordshire and

* *Trans. Fed. Inst.*, vol. vii., page 287.

East Worcestershire Institute of Mining Engineers, the speaker showed that there is an outlier of old Coal-measures covered over by Upper Coal-measures, and occupying an area of about 12,000 acres. We must remember that there is a patch of older Coal-measures lying still farther to the west, at the Brown and Titterstone Clee hills, showing that a great sheet of the older Coal-measures once extended in that direction, how far it would be difficult to say. But he must remind the members that at Newent coal-seams are found thrown down by faults. This suggests a connecting link between the Shropshire area and the Forest of Dean at some stage of the Carboniferous period.

Mr. De Rance has brought out very clearly that "the whole gist of the accumulated information tends to show the extreme variety of the conditions obtaining at any one point, and further that each small area must be judged and considered on its merits, and that without actual boring the judgment of the expert, however experienced, may be at fault." Nothing can be more to the point. That is an argument against correlations of Coal-measures at considerable distances from each other, but he contended that correlation is not to be put on one side on this score—it has its uses.

The area with which he was mostly acquainted, among those to which the paper applies, lies between the Coalbrookdale coal-field and that of South Staffordshire, and his opinion at present is that there is an unknown area of denuded older Coal-measures along the eastern sides of the Coalbrookdale and Forest of Wyre coal-fields. The denuded area is filled with Upper Coal-measures which, as they approach the denuded escarpment of older Coal-measures, rise upon it, and are consequently there thinner, and as one goes farther east they thin out altogether. Then we find that the Permian also thins out, so that at the Cannock and Huntington sinking-pit the pebble-beds rest on the older Coal-measures.

On the eastern side of the Forest of Wyre coal-field there is an immense thickness of Upper Coal-measures. He considered the whole of the strata in the Shatterford pit, which was sunk and bored 957 feet, to be Upper Coal-measures, but Mr. Cantrill has shown the members that overlying these there are red Upper Coal-measures with a band of *Spirorbis*-limestone hitherto unknown, which has been called Permian, and he was pleased that Mr. De Rance for the moment called it "*quasi*-Permian."

Then we meet with the Permian conglomerates as we go west, and we know that we are in ground better known and identified as Permian. It is of less importance to enquire what is the depth to productive

Coal-measures south of Bridgnorth, than it is to ascertain whether they exist there at all. The indications are that the denudation represented by the Symon fault has swept away a large area of the older Coal-measures in that region. That is the reason why he had always contended that proofs of the underlying Coal-measures should be made from the Staffordshire side, where we know that dislocation and not denudation has caused the disappearance of the coal.

Several bore-holes have been put down in the Trias and Permian in this area, but none of them have been deep enough to pierce the Coal-measures. The most important is that at Cosford waterworks, 918 feet deep, and left off in what is called the Lower Bunter. The sinking and boring at Goldthorn Hill was entirely in Permian measures, as also were the borings at White Cross and the Bank near Claverley, 504 feet, which passed through three bands of conglomerate. Other borings at Swindon, Ashwood, and at Highgate Common were in strata still higher, and threw no light upon the question before the members.

It is proposed to put down a bore-hole in Himley Park and another farther north, but it is useless to commence unless they are prepared to bore to a depth of at least 2,100 feet if necessary. His (Mr. Jones') impression is that it will not be necessary to go so deep, but there is a possibility of it, and therefore they should be prepared for the greater depth. They must remember that many geological features besides denudation in the Coal-measures lie hidden beneath the Trias. There may be warps and folds and volcanic masses, such as Powk Hill, near Walsall, covered up by Triassic rocks. There are at Chillington, near Codsall Wood, three separate sulphur springs issuing out of Triassic rocks, a most unusual thing, and only accounted for by some exceptional occurrence in the strata underlying them. To account for them will be an interesting enquiry for the geologist. He hoped that Mr. De Rance would continue to collect evidence upon this important question, and that mining engineers would give him all the assistance they could.

Prof. HULL said, as regarded the Forest of Wyre, that through an oversight he did not state the extent to which mining engineers and geologists were indebted to Mr. Daniel Jones for his elaborate observations which were published in the *Geological Magazine** some years ago. He was delighted that he had been able to be present that afternoon and give them from his own recent and personal knowledge some further observations. He entirely concurred with him that in the Forest of Wyre they had representatives of the Middle Coal-measures

* 1871, vol. viii., pages 200 and 363.

as well as of the Upper, and if he had the opportunity he should take care to correct the statement made so many years ago to which he had referred. He concurred with nearly all that Mr. Jones had said on that particular subject.

Mr. C. E. De Rance wrote that Prof. Hull in speaking of the author being inclined to regard "the great series of red marls, sandstones, breccias, and conglomerates overlying the Coal-measures of the Midland districts and Shropshire, as referable to an uppermost Carboniferous stage," still thinks with the late Sir Roderick I. Murchison, that "they are the well-recognized representatives of the Lower Permian (*Rothe-todte-liegende*) series of Germany, which is highly unconformable to the Coal-measures of that country." This argument appears to the writer to cut the other way, as in England these beds are strictly conformable to undoubted Upper Coal-measures, both in Warwickshire and in North Staffordshire, the break, when present, being between the latter and the Middle Coal-measures.

Mr. T. Crosbee Cantrill suggested that the Midland red rocks "would be better described as Upper Coal-measure passage-beds, *i.e.*, a series forming a gradual passage from the Coal-measures to true Permian and Triassic rocks;" this suggestion the writer thinks eminently useful and practical, except as to the addition of the Triassic rocks which are unconformable to the highest degree on the Permians, and overlap them over wide areas. Mr. Cantrill's second suggestion of "Red Upper Coal-measures" as distinguished from the ordinary "Yellow Upper Coal-measures" which underlie them, the writer considers inapplicable; thus in North Staffordshire more than 1,500 feet of red measures intervene between the yellow measures above and the grey Middle Coal-measures below. These red measures consist of marls in which occur green grits and sandstones, thin coal-seams, limestones, and black-band ironstones.

The more closely the Zechstein Permian of South Lancashire and North Cheshire is studied, the more variable and subject to local unconformities is it found to be, varying 1,000 feet in a few miles; and the more probable does it become that the so-called Lower Bunter is the sole representative of the true Permian south of Prof. Hull's concealed Carboniferous ridge, and even this is constantly absent, the Bunter Pebble Beds resting upon rocks of all ages, without its intervention. The overstepping of the supposed Lower Bunter, over the so-called Permian series, referred to by Mr. Cantrill, east of Bridgnorth, as evidence of the latter being really of Coal-measure age, the writer cordially agrees with. He (Mr. De Rance) thanked Mr. Daniel Jones for his kind expressions, and

noted that he agreed with him, as to the importance of judging each area on its own merits, and the variety of conditions that have prevailed.

After reading the discussion, he (Mr. De Rance) was anxious to state that he had arrived at the following conclusions :—

(1) The presence of the Keuper formation in Lancashire, Cheshire, and North Staffordshire renders it probable that the Bunter lies beneath to the base of the Pebble Beds, the latter being recently proved at Bidston (west of Birkenhead), in a futile search for coal, to be no less than 2,000 feet thick ; but there is no necessary connexion betwixt these Triassic rocks, and the true Permian, or Zechstein, which may or may not be present. South of Prof. Hull's Carboniferous ridge of Cheshire the Keuper often overlaps the Bunter, which latter is wholly absent in the Nuneaton district, the thick Keuper building-stones of Cheshire also having dwindled to a few inches, and they rest indiscriminately, on either the Middle Coal-measures, or the pre-Cambrian rocks beneath them.

The presence of the Bunter Pebble Beds does not necessarily imply that any members of the Permian or Coal-measures are present beneath, as the rocks of this horizon, through earth-movements and contemporaneous denudations, are found resting on all members of the Permian and Carboniferous series, down to the so-called Yoredale Grits (basement Millstone Grits).

The Zechstein, or undoubted Permian measures of South Lancashire and North Cheshire, may or may not be present at any point of which the details are unknown in that area, making a difference of more than 1,000 feet.

The presence of the Zechstein measures in Lancashire or Cheshire is no guide, as to what may happen to underlie them. For instance, at Bedford Leigh they rest on the highest Upper Coal-measures, while at Skillaw Clough, near Ormskirk, in the same county, only 12 miles distant, they rest on the Millstone Grit. South of the Cheshire concealed Carboniferous ridge the Zechstein never occurs, and the measures intervening between the base of the Trias and the undoubted Upper Coal-measures are referred by the older writers to the Permian *Rothe-todte-liegende*, and by the more modern to an uppermost member of the Upper Coal-measures. It is worthy of note that this is always strictly conformable to the undoubted Upper Coal-measures, which generally consist of yellow measures above, and red clays with green sandstones below. These may rest on the Middle Coal-measures, or any older rock in the vicinity, the older Coal-measures either having been denuded away or never deposited. He (Mr. De Rance) was investigating and

plotting, on the 1 inch Ordnance Survey maps, isolithic contours, *i.e.*, lines of equal thickness of strata, at 100 feet (vertical) intervals, in the Midland counties, which, when complete, will give a section in any direction across the Midland district. Towards this end, he would be grateful for records of sinkings through any measures lying above the Middle Coal-measures, from members disposed to assist in the work, which, if it can be effectually carried out, cannot fail to be pregnant with commercial and economic results.

The discussion was then closed.

Mr. F. G. SHAW read the following paper on "The Gold-fields of Matabeleland":—

THE GOLD-FIELDS OF MATABELELAND.

By F. G. SHAW.

Until the beginning of the year 1894, the Matabele country was practically unknown, and was inhabited by one of the most bloodthirsty races existing. Rumours of immense ancient workings were circulated by hunting men, who had penetrated into its interior, but Lobengula (the late king) prohibited anyone from visiting the workings, and the Matabele, acting under his orders, prevented any traders from investigating them. In the beginning of 1894, Lobengula was overthrown, and the Chartered Company were in possession of Matabeleland, a country half as large again as England, possessing a warm, fine, and, in most places, a healthy climate. It forms a part of the big table-land which exists in the central portions of the South African continent. The average elevation of the whole of the country is 4,700 feet above the sea level.

Lying partly in the tropics, it has the warmth of a tropical country tempered by an elevation sufficiently great to render it an extremely pleasant climate for Europeans. The rainfall appears to be regular, and continues through November, December, January, and February. The rains are not heavy or excessive, so far as we know ; thunderstorms occur before and after the close of the rainy season. The country is an extremely well-watered one, and numerous large rivers exist, having many tributaries. The gold industry is not likely, therefore, to suffer any hindrance from failure of water ; and although water-power, during the whole of the year, will not be obtainable, save in a few instances, there will always be sufficient water, with judicious conservation, to supply the necessities of the gold mills.

In the Victoria Falls, on the river Zambesi, some 150 miles from Buluwayo, there is undoubtedly sufficient power to run all the machinery required for the next twenty years in the numerous gold districts, and a company has already been floated to utilize this source of power.

Timber, so far as fire-wood is concerned, is plentiful, and in the fine forests to the north of Buluwayo exists, practically speaking, an inexhaustible supply of splendid hardwood timber suitable alike for mining, ornamental, and household purposes. Some millions of acres of this

timber forest are either held by private companies or held as reserves by the Chartered Company, so that no scarcity of timber is likely to occur. Apart from these forests, excellent mining timber is common in the vicinity of many of the gold districts. The *Mahoba-Hoba*, *Mapanie*, *Knobydorne*, and *Harden* wood are among the best timbers for mining purposes; these trees, however, do not grow to a very great size, but are sufficiently large for underground timbering purposes. The white ant and the borer attack most of the other woods, so that apart from the timbers, which have just been mentioned, the other varieties can only be used for temporary purposes.

Coal-fields have been found in various parts of Matabeleland of a similar character to those existing in the Rand district, but no work has yet been done on them, and it is impossible as yet to express any opinion as to their value.

Iron ores of the finest quality are abundant, and have been largely worked for a considerable period of time by the natives of the country, and it may be considered that from this source alone, a most important industry is likely to arise, and eventually to rival the output of other countries.

The labour supply is, at present, not in as good a position as it may confidently be expected to assume within a short period. The natives of the country, living as they have done for many generations as hunters and warriors, are adverse to manual labour, and are, besides, unused to work. The Chartered Company are wisely encouraging these men to work, and there is no doubt that from the natives the labour required in Matabeleland can be supplied. There is besides this, however, on the eastern boundary, a very large supply of native labour. The countries which contain this working population have been supplying Kimberley and the Rand for a number of years. The Shangans, Machoopies, etc., etc., are the best native labourers in South Africa, and it is more convenient for them to work in Matabeleland and Mashonaland, than to perform the journey of 600 or 700 miles to reach the Rand, or 900 or 1,000 miles to go to Kimberley. The various companies at work in Matabeleland can therefore regard the question of labour supply with satisfaction.

Although Buluwayo is 600 miles from the nearest railway, transport is by no means very difficult. The average price asked for freight from Mafeking to Buluwayo is about £20 per ton, and although this seems at first sight to be a heavy charge, still it does not materially affect the money expended in developing a mine, erecting machinery, etc. Neither

should the time occupied in transport present any difficulty to the rapid development and success of the gold districts. Foresight and economy are undoubtedly wanted here as elsewhere, both in ordering goods in sufficient time to arrive on the ground when required, and in checking any needless expenditure of money, or loss of time, caused by the omission of any necessary portion of the machinery.

The gold-belts of Matabeleland cover, roughly speaking, one-third of the area of the country, and already over 1,800 lineal miles of reef have been pegged : most of this ground consists of reefs which have already been worked by the ancients. Vast as this area undoubtedly is, it does not represent to the ordinary gold-miner the extent of reefing ground which is really held. Under the mining laws of the Chartered Company, the pegger of the outcrop of any reefs or series of parallel reefs, has the right of following them down to any depth he chooses, so that no deep-level claims or block-claims, as they are called in Australia, are necessary, and, consequently, a mile of reef pegged in Matabeleland is equal to four or five miles pegged on the Rand or in Australia. Few virgin reefs have up to the present time been either pegged or looked for, and the author anticipates a great future for the gold industry, when legitimate prospecting is carried on. It has been a simple matter to peg out the old workings, or the reefs existing on the extensions of such old workings ; these old workings are at once apparent and have not required that careful and systematic search which has been given to the discovery of reefs in Australia and America ; consequently, unskilled men were placed on equal terms with the experienced prospector. It has been, however, decidedly more difficult to discover the value and size of the reefs so worked by the ancients, as they have sunk on an average to over 30 feet in depth, and in the course of the centuries which have elapsed since their work was performed, the mullock and *débris* surrounding the holes and shafts and stopes have silted in and buried the reefs where left by the ancients to a depth of from 20 to 30 feet. It has, therefore, been necessary to penetrate, by means of shafts, the mass of detritus existing over the lodes before discovering their value ; in most cases rich reefs have been found. The only indication which the mining prospector in Matabeleland had prior to the discovery of the reef by shaft-sinking, was the *débris* or mullock left on the surface by the ancients. From the result of 18 months' work in Matabeleland, the author would be inclined to estimate the average value of the smaller fragments round these holes as giving at least 7 dwts. of gold to the ton, and he has obtained from average samples existing round some of the old

dumps, as much as 2½ ounces to the ton, while individual floaters are very commonly found carrying from 2 to 20 ounces to the ton.

The reefs discovered at the bottom of these ancient workings, as well as those found outcropping through the country, belong to two distinct varieties: the interbedded, which are the most common reefs in the country, and the fissure-lodes.

The geological formation of the country containing the interbedded reefs is an upturned series of shales, slates, and schists, and it is in the planes of stratification of these rocks that the interbedded class of reefs has been formed. Before the rocks of this geological series were upturned and foliated, as they are now, they had been deposited as a series of mud-stones, clays, and shales in a horizontal position. After their tilting, probably caused by the natural contraction of the earth's surface, the lines of their stratification became channels through which infiltrating water could penetrate. This water naturally has followed the line of least resistance, and when carrying any minerals in solution has deposited them, when the circumstances were favourable, in the ground through which it penetrated. When the ground forming these channels was particularly soft and soluble, it would be washed away and displaced, and masses of minerals varying in thickness of the nature of quartz would be formed in its place, thus producing the reefs known as interbedded reefs and accounting for the inconsistent and varying character of these lodes. As the lines of stratification through which the water passed would frequently become impervious, so no doubt the water, following the line of least resistance, would be diverted (probably through some cleavage-lines) and seek some parallel plane of stratification in which an easier channel would exist, depositing always when the circumstances were favourable, the minerals it held. The above fact has always rendered this class of reefs of a difficult nature to mine.

Fissure-veins exist alike in the schistose and in the granite country, and are formed by deposition of minerals carried by the water penetrating through fissures or cracks existing in the crust of the earth, and cutting through the various strata it encounters, in obedienee to no regular or known law, and without regard to the strike or dip of the country.

These infiltrating waters laden with the minerals forming both these classes of reefs would naturally alter the country-rock in the vicinity of the channels through which they passed, and so the shales, mud-stones, etc., have been altered to schists, slates, etc. In the case of the interbedded class of reefs, it might be expected that series of parallel veins, lying

close together, would exist in rocks offering any opportunity of passage for such infiltrating waters, and thus many parallel reefs might be expected in them. This is what happens in the interbedded reef country of Matabeleland; as many as ten parallel veins within a short distance have been discovered to be auriferous, and in the Germania adit, eight parallel reefs are found within 85 feet (Figs. 1, 2, 3, and 4, Plate VII.) while an average of three parallel reefs have been already discovered. It might be expected from the geological conditions of the country, that the whole of Matabeleland would contain reefs; that this is so is beyond doubt, but it has not been discovered that these reefs are invariably auriferous.

The prospecting (to use the word in its true sense) of this vast country, containing as it does so very few mining engineers, at present, has not, in the author's opinion, been more than begun, for the pegging of the large number of reefs has been due to the indications left by the ancients. They, however, only worked on the reefs they discovered, which were at that time outcropping above the surface of the earth. As the denudation which is constantly going on, all over the world, exists here, it will be apparent that many reefs that did not then outcrop, must be doing so now, and the legitimate prospecting of the country for gold-reefs, if undertaken by careful, hard-working and experienced prospectors, a class which has not so far appeared in Matabeleland, would no doubt lead to a much larger area of auriferous ground being taken up.

The following questions may be considered in connexion with these classes of reefs:—Do these reefs penetrate the ground to any depth, and do they carry their gold downward as well as on the surface? As far as it is possible to judge from development work, the reefs not only exist to the 300 feet and 400 feet levels, but are in most cases even strong and rich when cut at the bottom of the stopes of the ancients, while the gold has been declared by those who have sunk these deep shafts to be equal if not better in quality as depth is attained. From a statement made to the author by Mr. Pauling, the minister of mines for the Chartered Company, it appears that in one old working in the Lomagunda country, the excavations left by the ancients in one spot are 1,000 feet in length, 500 feet in width, and 200 feet in depth. The bottom of this immense open pit is covered with *débris*, and in this a shaft was sunk to a depth of 70 feet before it cut four auriferous reefs of a distinctly payable character. In this case the ancients have gone down to an extent hitherto unknown, and the

immense hole they have left reminds one of the pit of the Kimberley diamond mine. In the 62 shafts which the writer has sunk in Matabeleland he has in the majority of instances obtained payable reefs at the bottom.

It is evident from these facts that the old miners did not stop working because the lodes had either ceased to go down or failed to contain gold; with their want of explosives, mining appliances, ventilating fans, hoisting plants, etc., etc., they would be unable to work at any great depth. Their dead-work was probably affected by the use of the pick, the hammer and wedge, and the action of water on heated rock. Instances of this latter method of mining are very common, and the smoke arising from the fire introduced in their mining operations still hangs on the walls of the old stopes. In many cases they had undoubtedly ceased work when they reached the water-level; they would have no method of pumping or contending against the water, which would naturally stop any attempts at using fire as an agent for disintegrating the rock. The necessary ventilation of such a method of mining would be most difficult to accomplish. The water-level would undoubtedly carry the line at which sulphides and refractory ores existed, and would render the ore it contained of little value to the old miners.

As far, then, as work has gone we do not find any absolute proof that the reefs are likely to pinch or become less auriferous in depth. Certainly, it cannot be adduced as a reason in favour of such a supposition that the old miners have ceased operations there for some time, and the class of interbedded veins (the most numerous in Matabeleland) are of a more difficult and less permanent character to deal with than the fissure-veins, still there are interbedded veins to a great extent, such as the Sheba, etc., etc., whose payable qualities are thoroughly known. The undoubted length of these reefs is an indication that they should extend to a considerable depth below the surface, and the great length of the ore-shoots, longer for interbedded veins than in any other part of the world, seems to indicate permanent gold in these reefs as they go down in depth.

It will be interesting to refer briefly to the theories connected with the class of ancient miners in this country and to the people who formerly worked there; most of these views are accepted by the people who have made a study of the circumstances and the data which exist. So far no official record has been found referring in any way to a bygone race of gold-workers. The Phœnicians seem by popular consent to have originally opened or started work on the mines

in this part of Africa. Their well-known navigating powers, their position as merchants in the olden days, and the fact that they traded in gold are matters of history. No records have been found in South Africa with regard to these long-past miners. The oldest Portuguese records state that when the Portuguese landed on the African coast, four hundred years ago, the curious workings were alluded to by them as old workings, but although the Portuguese were then the leading race for enterprise they do not seem to have been able to discover anything authentic or even to hazard any opinion as to who these people were. It is hoped that the records in the Vatican may contain some chance allusion to this interesting fact, and they are now being carefully searched by a savant with the hope that some light may be thrown on this extremely interesting question.

As far as one might be allowed to hazard an opinion, the author considers that the original workers of these mines were an educated Caucasian race, and that since their time these mines have been worked by at least two other distinct races of gold-miners. It is probable that the earliest race, if it was the Phœnicians, employed the good old-fashioned method of using the Gideonites in that part of the world to be hewers of wood and drawers of water to the conquerors, and had probably vanquished and reduced the negro races of South Africa, using them as labourers in their mines. Dissensions or wars at home might have interrupted them when in the pursuit of this industry, and cut off from their home and supplies, a partial evacuation of the country may have taken place, followed by a rising of the subservient race and the total extinction of the dominant race. Their buildings, their tools, and various appliances would very likely be used by the men whom they had partially educated, and the rougher and less civilized method of mining would very probably be carried on by those who had begun to appreciate the value of gold. This would account for the total disappearance of the early tools used. Whether or not this has been the case, it is certain that the earliest mining efforts have been followed by very primitive methods, which would indicate that the rocks and dumps of stone hitherto mined, and very likely but roughly sorted, had been turned over and over with the view of all rich pieces of quartz that had been left, being obtained. Work has also been carried on in a primitive style underground; striking stones of tough igneous rock are very numerous, and where the gold has existed on one wall of the reef more than the other, the auriferous quartz has been chipped off by these striking stones.

The ruins which exist are in many cases in good preservation, and are extremely interesting. It has been considered that Zimbawe was built by people of the Phallic religion; but there is a great deal yet to be found out about these ruins. When the writer was in the northern parts of the Transvaal visiting old workings, the oldest resident, an aged Boer, whose parents settled there when he was a boy, informed the writer that the natives at that time spoke to his father of a race of black men with long hair, who worked these mines. The author considered at the time, and in an article written in 1892 on the subject, that it may not have been impossible that natives from India had visited the shores of Africa and worked for gold there, as they worked in the Mysore and other gold-districts in India. The similarity of the old workings seemed to the writer to be a strong argument in favour of this view. Phallic worship is common in India, while the monsoon winds would form a ready means of navigation from one place to another.

Copper has undoubtedly been worked in the Transvaal by old miners. This, again, is a mineral highly prized by the Indians, and also worked by them. So it may be quite possible that Indians are to some extent answerable for some portion of the old workings which we now find. When these old workings were first discovered, their extreme age was not suspected, and the filling up of the shafts was considered to be due to the deliberate action of the natives living in the country. The author's investigations have convinced him that the filling up of these old workings has been due to the action of time, and places the date of the earliest mining at a very remote period. The only crushing appliances now found are a vast number of mortar-holes, with oblong rounded stones which have evidently been used as pestles. These holes are found in tough igneous rock, generally in the vicinity of streams, most often in the rivers. The auriferous ores were evidently brought to these mortars and pulverized, water being allowed to flow into them and carry off the light matrix, leaving the gold at the bottom of the holes. This could easily be extracted by means of clay on short sticks, the gold being again freed by the immersion of this clay in vessels holding water. Time and labour being of little value, this laborious process would pay well with the rich class of ores which exist in Matabeleland.

We will now turn to practical work, the result of which will undoubtedly carry greater weight than any opinions expressed on the general aspect of the country. The author has put down 62 shafts in different parts of Matabeleland, and has, in this manner, done over 3,000 feet of dead-work, resulting in the discovery of a number of very payable lodes.

BELINGWE DISTRICT.

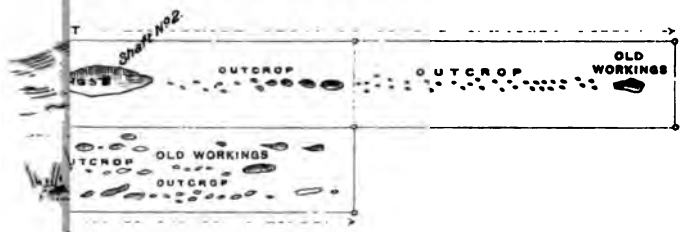
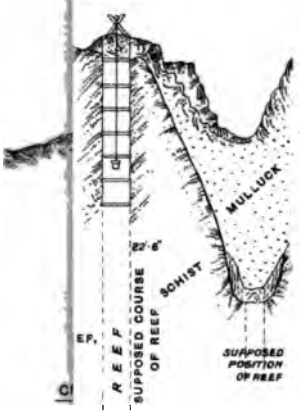


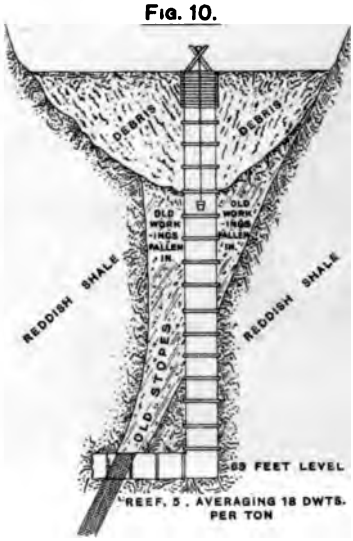
FIG. 10.

FIG. 7.



TION OF SHAFT No. 2.

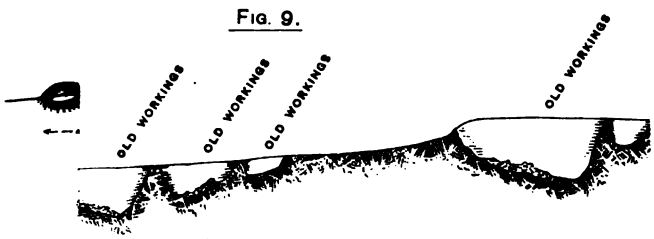
(THETA REEF)



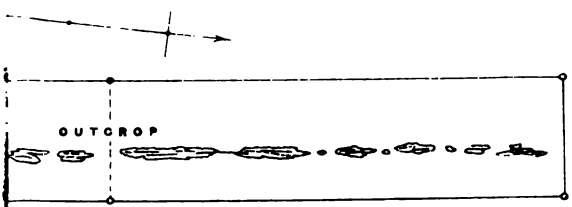
SECTION OF SHAFT.

(LONG JOHN REEF)

FIG. 9.



SECTION.



The average width of the reefs discovered in these 62 shafts is considerably over 2 feet, whilst the assays from fair sections of the reefs, taken in the most careful manner, gave a result of over 1 ounce to the ton. The ore, as far as work has been done, appears not to be of a refractory nature, although of course refractory ores exist, but the author does not anticipate serious difficulties from this reason, provided always that skilled men are employed.

The Germania reef is situated in the Belingwe district (Figs. 1, 2, 3, and 4, Plate VII.); it is of the interbedded class of reefs, and has been most extensively worked by the ancients. One shoot of gold extends to 2,200 feet in length, and has been worked to a depth of at least 45 feet from the surface. In No. 1 shaft, at a level of about 60 feet from the surface, the bottom of the old stopes was struck, and 2 parallel reefs were discovered, 3 feet of rock separating the two reefs. One of these reefs, 22 inches in thickness, yields an average of 18 dwts. to the ton, whilst the other, which is about 30 inches in thickness, yields an average of 1 ounce 5 dwts. to the ton.

The Theta reef is in the Sinombi district (Figs. 5, 6, and 7, Plate VII.). Here another long line of old workings exist, in which two shafts have been put down and two reefs have been struck. About 3 feet of solid matter in one reef gives a return of over 5 ounces to the ton, whilst in the other shaft 2 feet of the reef assays 3 ounces 3 dwts. per ton. The old workings, as in the Germania reef, are deep and continuous, and from panning the stone round the waste-dumps, it is discovered that the smaller stones are very rich, in the case of the Theta reef giving a return of over 2 ounces to the ton.

The Long John reef is in the Guanda District (Figs. 8, 9, and 10, Plate VII.). The section (Fig. 10) shows to what depth the ancients had worked, and how a modern shaft has been sunk to a depth of 63 feet, and a level run at right angles to intersect the reef which was found to exist in the old workings. At a depth of 63 feet the reef was ascertained to have a width of 5 feet, with an average gold-contents of about 18 dwts. to the ton.

The author anticipates that with careful management and able control, the gold-reefs of this country will eventually produce as much gold as any country in the world, and it seems probable, after a consideration of the vast nature of the work which has been performed here in bygone ages, that to this country the world will owe to a great extent its supply of gold.

Mr. W. COCHRANE (Newcastle-upon-Tyne) said that the members must be grateful to Mr. Shaw for his paper. He would like to ask him whether he understood him rightly to say that at the present moment the Matabele development of gold discoveries were simply due to the sagacity of the ancients? Had any discoveries been made by new prospectors except upon the old lines of the ancient worker, and was there any indication how, exercising their sagacity, as at the present time we did not seem able to do, they came to the particular localities where gold was? Was there any sign of "hushings"—water running down the hillside and washing the land away, and showing the outcrops of reefs to the surface? No doubt there would be relics of the system on the surface in Matabeleland if this method had been adopted, and if Mr. Shaw's theory that this gold-deposit was formed by infiltration and not by volcanic agency was right, it would seem to be difficult for the reefs to be revealed on the surface. He would like to ask Mr. Shaw why he was so certain that infiltration had formed the veins? They had heard Mr. Shaw's experience that, in going down to the level where the ancient miners had left off, he found very valuable quartz. He would like to know whether, in his opinion, the ancients left off because water had collected, and they had no means of contending with it?

Mr. STOKES (H.M. Inspector of Mines) asked Mr. Shaw to inform the members as to the mining rights in the country.

Mr. SHAW, replying, said he did not think that the ancients had discovered the reefs by any system of hushing. He thought that they discovered the gold in the reefs simply by prospecting the outcrops. The reefs in Matabeleland were of the richest class of reefs, and it would be an easy matter to discover the gold when visible at the outcrop. As to whether the prospectors had discovered reefs apart from the old workings of the ancients, he might say that they had discovered the Eileen reef; it had been pegged out for a length of 27 miles, and he believed that there were more than 30 shafts down to a depth of at least 60 feet: the peculiarity of this reef is that on the surface it is not particularly rich, but as depth is obtained it becomes thicker, stronger, and richer. At one end of it, there were some old workings, but they did not exist along its entire length. Mr. Cochrane questioned him as to the formation of the veins being due to infiltrating water. He thought so. The shales and mud-stones, when they were tilted, naturally formed channels for infiltrating water. At that time the crust of the globe was subject to submergence, and as he had pointed out in a previous paper on the "Auriferous

Conglomerates of the Witwatersrandt,"* the proportion of gold existing in the waters of the ocean was much greater than at the present day—great as it undoubtedly is. And the process of segregation was going on from the saline and other matters in the ocean, and in the days when these mudstones were covered by the waters of the ocean, the waters existing on the surface impregnated them to a great extent, and with the other minerals held in solution thus formed the reefs. The reason of the reefs being easily discovered is because they are harder than the casing which holds them, and the quartz is harder than the surrounding country. Stone-lined shafts existed, yet they did not seem to be shafts put down for working, but for the purposes of ventilating the mines. In the vicinity of the big workings, stone-faced shafts existed, having an average diameter of 2 feet, and these appeared to be very old. The theory of the manner in which the ancients worked was that when they got to stone, which was rich enough to mine, and which was too hard for their appliances, they built fires down below, and thus heated the rock, they then threw water upon it, and decrepitated it. When the shaft reached the water-level of the country, mining would become more difficult, as they had probably no other method of overcoming the water than bailing, and mining by fire would become impossible. He did not know how the ancients dealt with the refractory ores, from which they could not obtain the gold by the simple process of crushing. In the Transvaal, the mining claims were 400 feet by 150 feet; in Matabeleland, instead of a prospector being allowed only a length of 150 feet, he was allowed 1,500 feet, and may follow the reef to any depths and any angles and variations. The sedimentary conglomerate-beds of the Witwatersrandt were quite different from the quartz reefs of Matabeleland. The conglomerates in Matabeleland, found in connexion with sandstone, have not so far proved to be auriferous, but little prospecting work had been done in that direction. The reefs of Matabeleland are much richer than the stratified beds of the Rand, but they are more difficult to mine.

The PRESIDENT moved a vote of thanks to Mr. Shaw for his paper, which was cordially approved.

The following paper by Mr. T. Scott-Anderson on "Electric Welding" was read :—

* *Trans. Fed. Inst.*, vol. v., page 169.

ELECTRIC WELDING.

By T. SCOTT-ANDERSON.

Introduction.

It will perhaps be desirable to devote attention to two processes, (1) the one named in this country the Benardos system, and (2) that of Dr. Zerener, which is called the deflected arc method of welding. In doing so, no injustice will be done to the earlier Thomson system if the writer refers the members to a paper on "Electric Welding," read by Mr. Dobson at the Manchester meeting of the Society of Mechanical Engineers.*

A fourth, the Hoho-Lagrange system, may be mentioned, but so far as the writer's knowledge goes, no plant on this method is yet working in England. The last-named process relies for its heating properties upon the following conditions:—A wooden tank (lead-lined) is filled with acidulated water to a density proportionate to the voltage or electrical pressure used, one pole of a dynamo is connected directly to this inner leaden sheath, and the remaining pole is coupled to the bar of steel or other article to be heated, this system therefore necessitates the use of a tank or bath large enough to receive the metal which requires heating. The moment the bar touches the water, electrolysis of the acidulated water is set up, the water is split up into its component parts, oxygen going to the leaden sheath, and hydrogen rushes to the bar of steel or other article which is being heated; these particles or globules of hydrogen cling to the metal, and form a complete gaseous envelope around it, so that the metal is actually no longer touching the water. The hydrogen sheath offers a large resistance to the flow of current, and the whole energy is thus transformed into heat. For case-hardening of small articles, for hardening and tempering of steel-wire, knife-blades, and similar articles, the process may find useful employment; but where large masses of metal have to be treated, the large expenditure of current would, in the writer's opinion, be prohibitive. One considerable advantage is, however, evident, viz., that the heating being

* *Trans.*, 1894, page 319.

effected under water no oxidation of the metal can take place. A continuous current at a pressure of about 200 volts is used for this process. The temperature, however, is not easily controllable, and the utility of the process appears to be confined to easily weldable iron or low-grade steel and to pieces of simple form. High carbon steel would be burned.

The Benardos or Arc System.

In the Benardos or arc system, the article to be operated upon is made to constitute one pole of the electric circuit, while a carbon pencil attached to a portable insulated holder, and held by the workman, constitutes the other pole, the electric arc (which is the heating agent of the process) being struck between the two poles thus formed. When steel or iron is being welded, it is usual to make the carbon the negative pole, and the steel or iron the positive pole; but, for other metals, the poles are sometimes reversed. In welding lead, for instance, it is usual to make the carbon the positive pole. This process has during the last two or three years been considerably improved in detail at the works of Messrs. Lloyd & Lloyd, Birmingham, and elsewhere. In Sheffield, eight plants are doing most satisfactory work in various ways.

The method of working is simple, and is practically the same in all cases. At Messrs. Lloyd & Lloyd's, several low-tension continuous-current dynamos are used. During periods of light loads, these dynamos are employed in charging a number of sets of Benardos accumulators or secondary batteries; at times of normal loads, the dynamos supply current direct to the welding-shops; when extra current is required, provision is made by which a large discharge from dynamos and batteries combined is obtained. In parallel, with the dynamo and batteries as many welders or welding-machines can be connected as may be desired, and every workman is able independently to vary his current and pressure to suit the work in hand at the moment. One terminal of each welding system is connected by means of a flexible cable to a carbon pencil held in an insulated holder, which is in turn held by the workman, while the other terminal of the system is connected to the table on which the work lies, or to the work itself. The special advantage of this arrangement of resistances and accumulators is that it admits of wide limits of variation of current and pressure to suit the different classes of work which may be in progress, and arrangements are made so that the works, offices, and foremen's houses are lighted, motors are driven, and the electric welding-plant is supplied with current simultaneously from the same system of mains. Each welder has a regulating resistance which is connected directly in

the path of the current, so that by merely moving a switch from one contact-point to another, the current and pressure is varied to suit the work.

In every other installation of the Benardos system, batteries are dispensed with. The efficiency of this method of direct working without the aid of batteries has been questioned, on the ground that when actual welding operations are not in progress, the whole plant is running light, whereas on the other hand, at these no-load periods, the steam energy is utilized in charging batteries. In the writer's experience, this seeming defect may be entirely obviated by arranging two or three welding-tables on the same circuit. When No. 1 welder has completed his work electrically, he proceeds to dress it up; No. 2 has then an opportunity of at once striking his arc, and so on. This, however, is not the only advantage, secondary batteries for welding purposes are costly luxuries, and their maintenance is a matter for serious thought, and even if the smaller efficiency is admitted, it after all becomes a matter of cost with each user. Method No. 1 has a greater first cost, its yearly upkeep is excessive, and its efficiency high. No. 2 method costs less than half, its yearly upkeep is small, and its efficiency from the consumption-of-energy point of view somewhat less.

In passing from this part of the subject, we come to a more important one, viz., what has been done by the Benardos system, and an explanation of the simplest and cheapest method of doing similar work.

General Repairs.—An eccentric rod of a reversing engine at Newburn was accidentally broken on August 13th, 1891. The engine was being tested under steam, when the eccentric rod bent and broke close to the double eye-neck. The eccentric rod being of steel, and the position of fracture so awkwardly situated that it could not be readily welded in the ordinary way, it was decided to straighten the bent and broken rod and electrically weld it. This was done, and the engine with the repaired eccentric rod attached was running under steam at six o'clock the following morning. The eccentric rod as originally welded is still working, and has never since given the slightest trouble.

A slot-link of a reversing engine broke, and stopped the mill. The broken pieces were placed together and electrically welded at the points of fracture, after which the link was fitted and erected, and the engine with the repaired slot-link was running again within one hour from the time of original breakdown. This slot-link continued to work for over twelve months without trouble, and until the engines were eventually removed.

One of the steel roughing-rolls for a bar-mill, which under normal conditions works with heavy draughts on hard steel, and the wobbler-end had become worn, until the coupling-box turned round without driving the roll, thus rendering the roll useless. The roll, which weighed over 50 cwts., was taken out and the worn portions electrically welded up again to their original size. The whole operation of taking out, welding, and putting in place again, only necessitated the mill standing for twenty-four hours. The welded roll has now been running for about twelve months, and although the wobbler is again wearing out, it is satisfactory to know that when it is again worn so that the coupling-box refuses to drive, the welding can be repeated again and again if necessary.

A cast-steel helical pinion weighing over 6 tons had been taken out and spare gear substituted, owing to the wobbler-ends being worn by the constant reversing of the mill. The wobbler-ends were electrically welded up to the size originally made when new, and the pinions put to work again on January 28th, 1895.

A shaft with flange-coupling keyed on one end. The continual reversing of the engine to which this shaft belonged, together with the heavy nature of the work done, started the keys, which in turn damaged the edges of their key-beds, and also the bed of the shaft-coupling. The damaged parts were welded up again, and the bed of the shaft-coupling turned, new key-ways cut, and the coupling keyed on as before. This example is only one of several shafts which have been treated in the same way—many of them being done *in situ*, and always with excellent results.

A cogging-mill live-roller, the outer case being of cast-steel with forged steel central shaft. These rollers are used to carry the hot ingots to and from the main rolls during the process of cogging ; and owing to the heavy nature of the work, especially in the immediate neighbourhood of the main rolls, the cast-steel outer cases frequently broke, leaving the central shafts unaffected. Several of these broken outer cases were electrically welded and again put to work, and although some of the electrically welded rollers which occupy favourable positions furthest away from the main rolls have been at work for nearly four years without fracture, it was found that the electrically welded rollers which occupied the most unfavourable positions nearest the main rolls continued to break ; sometimes at the weld, and sometimes through the unwelded parts without distinction.

Apart from the general work done by the Benardos process in the repair of slightly defective steel-castings, many other instances might be cited where repairs of a similar nature to those already described have

been done, such as welding in the teeth of cast-steel wheels which have been broken while working, without removing the wheels from their shafts; but one more example must suffice before proceeding to treat of the application of the process to boiler repairs.

A steel hydraulic ram, forming part of a hot-bloom shear. The end of the ram was originally circular and too far away from the cutting edges of the shear-blades to prevent the short crop-ends from tilting up and jamming between the shear's apron and the ram. The ram was taken out and electrically welded, so that now the foot of the ram is rectangular, and since being welded it has worked under the conditions named for about three years without giving the slightest trouble.

Boiler Repairs.—One of the first applications of electric welding to boiler repairs was made in September, 1891, at the Newburn works. A vertical boiler was provided with an outer casing lined with firebrick, built in the form of flues, which completely encircled the outer shell of the boiler. The defect, situated at the point where the outer shell of the boiler was riveted to the bottom-plate, had originally existed as a leak, which, not being visible from the outside, had caused considerable corrosion before it was discovered. When the corroded parts had been cut away to full plate thickness, a hole was left in the outer shell, $5\frac{1}{2}$ inches long by $3\frac{1}{2}$ inches deep, and extending round the bottom flange of the outer shell in the immediate vicinity—a somewhat difficult place to fix a patch without removing the internal fire-box. Before commencing to electrically weld the defect, a piece of mild steel plate was bent and dressed to fit the outside of the boiler-shell and bottom-plate, and having $1\frac{1}{2}$ inches of lap over the hole. The patch-plate was then laid in position over the hole, and the electric arc struck upon the junction of the patch and boiler-shell, so as to melt together and thoroughly incorporate the patch with the boiler-shell and bottom-plate which it overlapped. Under the action of the electric arc, the outer edges of the patch-plate were gradually drawn away to nothing, and made to lose themselves in the boiler-shell and bottom-plate. The internal fire-box was not removed or otherwise disturbed during the progress of the work, and after being welded, the boiler was tested under a pressure of 140 lbs. per square inch and found perfectly tight; the whole operation of fitting the plate, welding, and testing the boiler only occupied 10 hours. This boiler has since been in constant use at a pressure of 70 lbs per square inch for six days per week, without showing the slightest indication of fatigue.

Another repair was made to the internal fire-box of a locomotive boiler, working at a pressure of 140 lbs. per square inch. In this case the mischief was corrosion at the bottom of the fire-box, in the neighbourhood of the firebars. The defects were welded up *in situ* by building on and melting into the recesses small pieces of mild steel, and thoroughly incorporating the new steel pieces with the old steel plate under the electric arc, and afterwards caulking the joints in the usual way. The firebars were removed—the workman taking up his position inside the fire-box and carrying the working cable through the firehole door. The welding when completed was very satisfactory, the leaks were stopped, and no further trouble has been recorded since the work was done.

Many other instances could be named where the arc-process has been used with every advantage and satisfaction in repairing boilers, some of these being done under the inspection of boiler insurance companies, and declared satisfactory by their inspectors.

Cutting and Boring.—Another very simple application of the electric arc is that of cutting and boring metals roughly to shape. In work of this kind, the same methods of procedure apply as in all the other cases cited, viz., that the article to be cut is made to form one pole, and the carbon pencil the other pole. Under these conditions, if the carbon pencil be brought into contact with the metal to be operated upon, an arc is immediately struck between the carbon pencil and that part of the metal in contact with it at the time, with the result that the metal is instantly melted in the immediate vicinity of the arc, and may be allowed to flow away as it is melted. In this way holes may be pierced in steel, iron, or other plates with great rapidity, and by gradually moving the arc the holes may be elongated into slits of any required length or shape at the option of the workman.

Plant and Apparatus required.—The plant and apparatus necessary to effect all ordinary repairs, or to perform the operations of cutting and boring, may be of the simplest description, and where an ordinary low-tension electric installation exists, practically everything necessary is in stock. In any case, however, where the necessary plant has to be provided for lighting, it may be arranged and made to serve the double purpose of lighting during the night, and welding, etc., during the day, provided that both duties are not required at one and the same time.

The dynamo should be of compound-wound type, having a capacity of 250 to 350 ampères at a pressure of 70 to 95, preferably about 85, volts. The cable from the positive terminal of the dynamo should be carried direct to the welding-table or to the article to be worked. The negative cable should be carried from the dynamo to the regulating-resistance, and thence to the carbon-holder, which the workman holds.

The face and eyes of the workman must in all cases be protected; that portion of the protector covering the eyes being of coloured glass, preferably in three separate thicknesses, and composed of ruby pieces. If the eyes are exposed even momentarily to the glare of a large arc, an effect is produced upon the muscles of the eye which, though not permanently injurious or of more than a few hours' duration, is very painful and disagreeable while it lasts. The effect produced upon the face or other tender portions of the skin by exposure to the radiant energy of the arc for any length of time—although not felt at the time of exposure—is similar to that produced by very severe sunburn, and becomes painful when an attempt is made to wash the parts with soap. When these precautions are taken, no trouble has ever been experienced, and the same workmen are now welding who have been associated with the process since its introduction. With a current of such low-tension it is impossible to get a dangerous or even unpleasant shock, consequently the machine or articles in circuit may be handled with impunity, and all the operations of welding, etc., carried on with the workman sitting or lying upon the articles which are being welded.

Necessary Precautions to ensure Sound Welds.—The carbons used should be uncoppered and of one uniform quality, sound and hard, and having a metallic ring when struck; they must burn with little or no dust deposits, otherwise the finely divided carbon deposited on the weld may be absorbed by the metal, which will thereby be rendered brittle.

When building up, the metal introduced into the weld should be as nearly as possible of the same composition as that of the article to which it is welded, and the workman should remove the slag formed on the surface of the weld, from each layer added before commencing to add another one. In cases where the part to be built up projects above the neighbouring surface (as for instance a wheel tooth), each layer of material added should be retained in position and prevented from flowing away while in a molten state, and this is best done (previous to the addition of each layer) by forming a ridge of finely ground gannister round the circumference of the layer to be added.

When the metal in the vicinity of the arc has been under the action of the arc for a short space of time, the heat gradually extends by conduction to the metal in the neighbourhood of the part operated upon, whereby the resistance of the metal to the passage of the current is increased, and admits of a longer arc being obtained than under conditions where the metal in the vicinity of the part operated upon is not so heated. The workman should always endeavour to obtain these conditions of heating of the surrounding metal, and to finish off each layer under the action of a long and steady arc, so as to ensure the gradual solidification of the metal added, and its subsequent annealing by the gradual radiation of the heat from the part operated upon, when the carbon is eventually withdrawn and the arc broken.

In all cases where it is possible to do so, each layer of new material added should be hammered immediately after the carbon is withdrawn and the arc broken; and where this is not possible, the withdrawal of the carbon, and breaking of the arc should be gradual.

Quality of Work.—In order that the capabilities of the Benardos process of electric-arc welding, in relation to the quality of work done, might be placed beyond doubt, 210 bars of varying thicknesses and qualities of iron and steel electrically heated and welded by ordinary workmen (not trained smiths), together with 50 bars welded by engine-smiths in the employment of another firm, out of a coke fire, in the usual way, were tested.

The results, as reported by them, will be found in Tables I. and II. The average ratio of weld to solid of the 150 electrically heated iron bars equalled 85·5 per cent., and of the 60 steel welds 80·8 per cent. A comparison between the table of results obtained from the hand-welded bars and those which were electrically heated will show that in every case the latter give a higher ratio of weld to solid than the former. In other respects, also, the comparison is usually favourable to the electrically-welded bars (see Table II.).

These experiments are believed to be the first attempt to demonstrate scientifically the value of the arc as a heater of iron and steel for welding purposes. The results shown were obtained by comparatively unskilled hands, and could be materially improved by continuous practice.

The welds were scarf welds, the length of scarf averaging $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. The results obtained from the welds of Low Moor and Farnley iron and Parkgate steel are satisfactory, the principal features being absence of cinder or impurities from the faces of the scarf, and the

TABLE I.—SUMMARY OF RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE STRENGTH, ETC., OF 10 ELECTRICALLY-WELDED BARS OF EACH OF THE UNDERMENTIONED SIZES AND BRANDS.

Material and Brand.	Nominal Size.	Description.	Ultimate Stress per Square Inch.	Contraction of Area at Fracture.	Extension in 10 Inches.	Ratio of Weld to Solid.
	Inches.		Tons.	Per Cent.	Per Cent.	Per Cent.
Iron, Low Moor	2 × $\frac{3}{16}$	Mean of solid ...	26·1	42·3	19·5	—
,, ,,	,,	,, welds...	21·1	17·3	7·3	81·1
,, ,,	2 × $\frac{1}{4}$	,, solid ...	24·8	45·7	22·9	—
,, ,,	,,	,, welds...	21·6	20·9	8·1	87·2
,, ,,	2 × $\frac{5}{16}$	,, solid ...	23·8	46·0	24·1	—
,, ,,	,,	,, welds...	21·8	20·7	9·7	91·8
,, ,,	2 × $\frac{3}{8}$	,, solid ...	24·7	41·7	26·7	—
,, ,,	,,	,, welds...	22·1	16·7	9·0	89·4
,, ,,	2 × $\frac{1}{2}$	,, solid ...	21·4	46·9	31·3	—
,, ,,	,,	,, welds...	20·7	19·2	10·2	96·8
Iron, Farnley ...	2 × $\frac{1}{8}$	,, solid ...	24·1	31·2	17·3	—
,, ,, ...	,,	,, welds...	20·7	6·5	4·4	85·8
,, ,, ...	2 × $\frac{3}{16}$	,, solid ...	26·4	37·4	18·1	—
,, ,, ...	,,	,, welds...	20·5	8·6	4·4	77·5
,, ,, ...	2 × $\frac{1}{4}$	,, solid ...	23·6	35·7	23·3	—
,, ,, ...	,,	,, welds...	21·6	17·6	6·5	91·6
,, ,, ...	2 × $\frac{3}{8}$	,, solid ...	21·9	49·4	27·5	—
,, ,, ...	,,	,, welds...	21·5	13·1	6·4	98·4
,, ,, ...	2 × $\frac{1}{2}$	,, solid ...	21·9	44·7	26·7	—
,, ,, ...	,,	,, welds...	18·9	10·5	4·6	86·4
Iron—Netherton ♔ best ...	2 × $\frac{3}{16}$	,, solid ...	23·2	23·5	11·2	—
,, ,,	,,	,, welds...	19·7	8·6	4·7	85·0
,, ,,	2 × $\frac{1}{4}$	,, solid ...	21·8	22·7	10·6	—
,, ,,	,,	,, welds...	20·1	10·8	4·5	92·0
,, ,,	2 × $\frac{5}{16}$	,, solid ...	25·1	23·7	18·0	—
,, ,,	,,	,, welds...	18·2	7·0	2·2	72·4
,, ,,	2 × $\frac{3}{8}$	,, solid ...	25·1	24·3	20·9	—
,, ,,	,,	,, welds...	18·3	5·8	2·5	72·9
,, ,,	2 × $\frac{1}{2}$	,, solid ...	23·9	29·5	23·2	—
,, ,,	,,	,, welds...	18·5	5·5	3·4	77·7
Steel, Parkgate, Yorkshire ...	2 × $\frac{1}{8}$	,, solid ...	30·3	57·1	22·3	—
,, ,,	,,	,, welds...	22·3	18·4	3·8	73·6
,, ,,	2 × $\frac{3}{16}$	,, solid ...	25·6	57·2	25·7	—
,, ,,	,,	,, welds...	20·8	16·0	4·2	81·2
,, ,,	2 × $\frac{1}{4}$	,, solid ...	25·3	57·4	27·0	—
,, ,,	,,	,, welds...	19·8	17·5	4·4	78·4
,, ,,	2 × $\frac{5}{16}$	,, solid ...	24·5	57·1	26·4	—
,, ,,	,,	,, welds...	20·7	17·1	6·1	84·7
,, ,,	2 × $\frac{3}{8}$	,, solid ...	25·0	54·7	26·0	—
,, ,,	,,	,, welds...	20·1	15·5	6·3	80·5
,, ,,	2 × $\frac{1}{2}$	,, solid ...	24·3	61·2	31·5	—
,, ,,	,,	,, welds...	21·0	15·4	7·3	86·4

NOTA BENE.—The mean results are based upon ten welds, as far as the ultimate stress per square inch and the ratio of weld to solid is concerned. But as regards the contraction of area and the extension, those results are the mean of the welds which broke (of necessity, where the weld did not break, the contraction or ultimate extension was not obtained).

maintenance of a fair amount of ductility at the weld, the material not being abnormally affected by the heating. Where the welds have come out low, the appearance of the fracture pointed to the metal having been either not hot enough or to the thin edge of scarf having cooled ere the weld was closed by hammering. In the case of the Netherton iron, there is a serious tendency to loss of ductility, the fractures being crystalline ; as there are, however, some good welds amongst them without these objections, it would appear as if the treatment, as regards the amount of heat, had not been adapted to the nature of the iron. In judging of the merits and capabilities of electric welding, due regard must be paid to the individual as well as the average results.

TABLE II.—SUMMARY OF RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE STRENGTH, ETC., OF 10 BARS OF EACH OF THE UNDERMENTIONED SIZES AND BRANDS HAND-WELDED BY SMITHS, COMPILED FROM THE DETAILED REPORTS.

Material and Brand.	Nominal Size.	Ultimate Strain Per Square Inch.	Contraction of Area at Fracture.	Extension in 10 Inches.	Ratio of Weld to Solid.	Figure of Merit. Ultimate Strain Multiplied by Contraction of Area at Fracture.
	Inches.	Tons.				
Iron, Low Moor ...	2 × $\frac{3}{16}$	20·3	15·2	7·3	77·9	308
,, ,, ...	,,	*21·1*	*17·3*	*7·3*	*81·1*	*365**
,, ,, ...	2 × $\frac{5}{16}$	21·5	22·3	11·3	90·7	479
,, ,, ...	,,	*21·8*	*20·7*	*9·7*	*91·8*	*451**
Iron, Netherton best	2 × $\frac{1}{4}$	18·4	10·1	3·4	84·4	185
,, ,, ,,	,,	*20·1*	*10·8*	*4·5*	*92·0*	*217**
Steel, Parkgate ...	2 × $\frac{1}{8}$	20·9	9·3	1·9	69·1	194
,, ,, ...	,,	*22·3*	*18·4*	*3·8*	*73·6*	*410**
,, ,, ...	2 × $\frac{1}{2}$	20·4	15·9	8·1	82·3	324
,, ,, ...	,,	*21·0*	*15·4*	*7·3*	*86·4*	*323**
						*1,766**
					118·5 per cent. =	1,490

* Electrically heated.

NOTE.—The figures in italics are the results given in Table I., obtained by electric heating, and are inserted for purposes of comparison.

The mean of the electrically-heated welds was 18·5 per cent. better in figure of merit than the mean of the hand-made welds.

THE DEFLECTED ARC SYSTEM.

The field covered by the Benardos system, just described, whilst being considerable, left something to be wished ; for instance, repeated attempts have been made to make electric seam- and lap-welds, and to carry on the

operations of brazing and soldering. With the Benardos system this is impossible: it was therefore necessary to find other means than those hitherto employed. The heat of the electric arc is probably over 3,000 degs. Cent., and with the Benardos system is concentrated on a small area.* All attempts to reduce the heat, and secondly to spread it over a larger surface, have failed.

Dr. Zerener, of Berlin, saw the difficulty, and he has devised apparatus which is supplying the want hitherto felt in this last-named process. The dynamo mains are connected (through the usual regulating resistances) direct to two terminals very much after the fashion of an ordinary arc-lamp with its regulating resistance in series. The current passes through the lamp-connexions to a carbon on the positive leg, jumps the air-space, and returns to the dynamo through a negative carbon again, precisely similar to the arc-lamp; but on each side of the lamp an electro magnet is arranged which is energized by a portion of the main current being shunted through it, and in exact proportion to the current absorbed or rather required by the carbons. Thus the moment current is switched on, a strong magnetic field is formed in which the arc is burning. This magnetic field affects the arc, and draws or spreads out the flame, and the extent of this drawing out can be adjusted at will. The members will at once note the difference between the two processes: in the latter, the welding apparatus is self-contained, the article to be welded is not in any way in electrical connexion with the dynamo, and the lamp may be raised or lowered, thus regulating the temperature of the heated article. These lamps are made in various sizes: the smallest one, requiring only 25 ampères at 70 volts., or roughly 3 horse-power, is capable of making 2,000 bicycle-brazes in a week of fifty-four hours, and is manipulated by one man. Up to a capacity of 75 ampères, the lamps are held by the workman, with a stronger current the apparatus is too heavy, and must be suspended over the work. The small lamps are adjusted by hand, but the larger ones are automatic, and feed themselves in the manner of an arc-lamp.

The regulating resistance and other accessories are in every way similar to those used in the Bernardos welding process.

Brazing.—A large variety of work has been accomplished in brazing copper tubes and flanges, copper to steel, brass to iron, and copper and zinc stampings as thin as $\frac{1}{32}$ inch have been successfully brazed without

* Simply because of the fact that the arc can only be formed between the carbon and the metal to be worked.

any running of the metal at junctions. Steel plates, up to ¼ inch thick, in the shape of barrels, for carrying oil, petroleum, etc.; water-cisterns, buckets, and other similar articles are electrically brazed. Perhaps the most extensive application of electric brazing has been found in the cycle industry, where the work is most economically performed, from the fact that the plant can be run at practically normal load throughout the working hours.

Welding.—The chief application in welding, up to the present time, has been in seam-welds on sheets or plates up to ½ inch thick.

Four boilers have recently been completed as a test for hot-water circulation for an American firm; the boilers were made of No. 14 gauge mild steel, they are 16 inches in diameter, and 5 feet long; after the sheet has been formed into cylindrical shape, the longitudinal weld is made, the ends of the boiler are convex, and are welded to the shell. With a temporary appliance, one boiler was completed in 55 minutes, viz., the longitudinal seam and two end welds; the current required was 230 ampères at 75 volts, and one man did the work.

Steel pipes have been very successfully seam-welded for a length of about 10 feet, having a diameter of 14 inches and thickness of ¼ inch. A sample was tested with the following result:—"Sample tested up to 450 lbs. per square inch, and, so far, appears perfect." Pipes varying from $\frac{1}{16}$ to ½ inch in diameter have been made with equally good results.

The seams are drawn up close, small pieces of mild steel are laid over the junction, and the process of welding goes on for some 6 inches; and when the fusion is perfect, the joint is hammered. The rate of working is about the same in all thicknesses, viz., about 1 foot in 7 minutes; the current used varies of course with the thickness of the metal.

A large plant has recently been erected in Hamburg for the manufacture of steel barrels, the capacity being equal to 100 barrels per week.

In conclusion, the writer begs to point out that this system of electric-arc welding is not proposed as a substitute in all cases for the ordinary methods of welding now in use; nor is it proposed as a substitute for riveting in high-pressure boilers, but rather as an additional method, capable of very extensive application, under conditions where the ordinary methods of welding are inapplicable.

The simplicity of the process and the portability of the plant, combined with the large field where such a system would be most valuable, are certainly good reasons for a more extended use. It is perhaps impossible to conceive a more useful application for electric-arc welding than the

general requirements of a large colliery. All kinds of repairs can be made, as shown in the examples recorded in this paper. The apparatus is always available, and in many cases there can be little doubt would effect considerable saving in the promptness with which these repairs would be effected. It may perhaps be as well to again affirm the fact that welding and lighting can readily be arranged from the same generating-plant.

Mr. C. J. OLIVER (Chesterfield) asked whether the process was applicable to welding cast-iron as well as wrought iron? If it were, he should like to know whether the metal was as strong afterwards, as before, being welded.

Mr. R. SHEARD (Wakefield) asked whether it was necessary to use accumulators, and what the cost would probably be for a plant adapted to welding boiler-plates?

Mr. DE GRAVE (Derby) said that he noticed Mr. Anderson said that "the yearly upkeep of accumulators was excessive." He had no experience of the Benardos accumulator, but he wished to remind Mr. Anderson that there are accumulators in which, leaving out of account interest on capital expenditure, maintenance is a very small figure. The accumulator he had in view was one of great mechanical strength, in which there is no paste or other equally objectionable matter to fall out and short-circuit the plates, and moreover, the cell is not permanently destroyed by being short-circuited for several hours. The question therefore of efficiency of accumulators is simply a comparison between interest on extra capital expenditure and cost of coal burnt in the boilers. It would, however, be a most exceptional case in which he would recommend the use of accumulators for such work. With regard to the weld in the eccentric rod—assuming this to be say $1\frac{1}{2}$ inches diameter, which would represent a very small engine, he would be glad if Mr. Anderson would inform him as to the method employed. He had some experience of the Thompson method, in which the arc was struck between the ends to be welded, the ends then being pressed together until united; but with the use of a carbon he failed to see how anything but a superficial weld could be made. He noticed that the results given in the tables at end of paper referred to bars of $\frac{1}{8}$ or $\frac{1}{4}$ inch thick, which could undoubtedly be easily welded with a carbon, whereas the inside of a thick bar could not be touched.

Mr. A. W. BENNETT thought that Mr. Anderson deserved the best thanks of the members for the large amount of information that he had given in a very practical form on a subject not generally well known. He imagined that the Benardos, or direct-arc system would be found most applicable to the rough-and-ready repairs required at a colliery. He asked Mr. Anderson to give the members the amount of power required in electric current and in horse-power for each of the items he cites under the heading of "general repairs." It would be very useful to mining engineers as a rough guide as to whether the system could or could not be introduced at any given mine, that is to say, whether, from a financial point of view, it would be advisable to adopt it.

Would it not be possible to use 100 to 110 volts, the usual current of moderate-sized lighting plants, with rather more resistance inserted, for small repairs, etc.? Was the capacity mentioned—250 to 350 ampères—for a colliery or for an engineering works plant? It appeared rather large for the former—practically a 500 lights machine. At some collieries, two or more 100 to 110 volts machines are employed for lighting, and sometimes for power-transmission. It would be a very easy matter either to reduce speed or insert a resistance in the shunt field-magnet circuit of one of these to get a pressure of 85 volts, when required. He thought that the subject was well worth the consideration of mining engineers. The results were satisfactory, and it appeared to be a question principally of the power required, which represented cost and maintenance.

Mr. CHARLES A. PARSONS (Newcastle-upon-Tyne) wrote that the beautiful method of the electric blow-pipe is for many purposes superior to either of the Thomson (low-tension) or Benardos (high-tension) systems, and that the control of heat is more easily accomplished than is the case with the Benardos or direct arc to the metal that is being worked. In 1885, he used an electric blow-pipe, but its practical application to welding was not then attempted. The regulation of the intensity of the flame by varying the power of the deflecting-magnet is very beautiful. If the strength of the magnet is very much increased, the arc becomes intermittent, and so great is the noise produced that it has been suggested that the method might be adopted for fog-signalling.

Mr. ANDERSON, replying, said that he had never seen cast-iron well welded. He had made a great number of attempts, but, as far as his experience went, none of them had turned out satisfactorily. Mr. Sheard spoke of the use of accumulators, and this might answer the other

questions put by Mr. De Grave. He did not think that there was any necessity for using accumulators, and as to their maintenance being high, he ventured to say and repeat what he had said in his paper: that the maintenance of an electric welding-plant employing accumulators, was excessively high, and he knew of no accumulator that would stand the wear-and-tear of electric welding. Accumulators were useful for ordinary purposes of lighting and where the output was regular, but when they required very large and sudden supplies of current for welding they would know that they must expect to get buckling of plates, etc. There was only one place where accumulators were used—at Messrs. Lloyd & Lloyd's, of Birmingham—where they had a large battery of Benardos cells, which are used for lighting and welding purposes. As regards the welding of the piston-rod, they cut the ends into a V-shape, placed them together, and welded the ends. This was then recut in another V-shape and welded again, and then it was tested by the chief engineer of the Newburn steel-works, and passed by him as a satisfactory weld. The bar-weld was done much in the same manner. The arc was not played round the bars. Boiler-plates up to $\frac{1}{4}$ inch thick had been welded, but he could not give them the tests. The plates were welded in one weld about 35 feet long by $\frac{1}{4}$ inch thick. For general repairs a current of 80 volts at 180 ampères, or roughly, 20 brake horse-power, would prove sufficient for any kind of work, and there would be no difficulty in arranging an 110 or 115 volts machine for this purpose.

The PRESIDENT moved a vote of thanks to the writer of the paper. He thought that it would be a matter of surprise to many of them that electric welding had been used for so many purposes, and, apparently, most successfully. There seemed to be some difficulties to be overcome, and one was the loss of ductility, but this difficulty did not appear to be sufficient to detract from the useful application of the process.

The vote of thanks was cordially accorded.

Mr. PLATT read the following paper on the "Coal-washing Plant at the Wirral Colliery, Neston, Cheshire":—

COAL-WASHING PLANT AT THE WIRRAL COLLIERY, NESTON, CHESHIRE.

By JAMES PLATT.

The necessity of separating dirt from coal is being forced upon colliery-owners more urgently as competition becomes keener, and as the best seams of coal become worked out or cannot supply the demand, the inferior and dirtier seams must supply the coal for the market.

When the matter is fairly and impartially considered, it does not appear rational to expect consumers to pay for dirt when they buy fuel. In addition to this, it seems wasteful to pay the carriage on dirt, and this is a considerable item when we consider that a large bulk of the slack-coal sold for manufacturing purposes contains from 10 to 25 per cent. of free dirt, *i.e.*, dirt which is free from the coal, and consequently ought not to be mixed with it.

Those who have a dirty coal to sell, in these times of depression, can well understand how their difficulties would be lessened if they only had clean coal to dispose of. The general experience is that it cannot be sold at anything like the value that there is in it as a fuel, if separated from the dirt; and how to do this effectually, and at least cost, is a matter for very serious consideration for colliery-owners.

At Wirral colliery, this problem forced itself upon the management, who, after looking for the most efficient and economical coal-washer in use, visiting and inspecting the most modern plants, and having samples of coal washed, decided to erect an Elliott coal-washing plant, which, on account of its efficiency, simplicity, and small cost, was most suitable for their wants.

The plant (Figs. 1, 2, 3, and 4, Plate VIII.) erected at Wirral colliery is capable of dealing with 100 tons of coal per day of ten hours. One washer only is fixed, but there is space for another washer, the other adjuncts, including elevators, shafting, conveyor, and power, being sufficient with slight additions for two washers.

The coal consists of all that will pass through a screen with 1 inch and 1¼ inches parallel bars; the dust, peas, beans, and nuts all being mixed

together. A vibromotor screen is provided, so that a separation can be made when desired, and the fine coal or the nuts only washed; or, if another washer be erected, each kind can be washed separately, one in each trough.

The Elliott washer (Figs. 5, 6, and 7, Plate VIII.) is designed on the principle of the trough-washer, with the difference that it is automatic and adjustable. It consists of a steel trough, 60 feet long, 1½ feet wide at the bottom, and 2½ feet wide at the top, the sides opening out from the bottom. This trough is fixed at an inclination of 1 in 12; and scrapers (taking the place of the fixed stops or dams used in the trough-washer) are attached at intervals of 6 feet to an endless chain, passing round sprocket-wheels fixed at each end of the trough, and caused to move slowly along the bottom of the trough from the lower to the higher end, and against the stream of water; the returning part of the chain and scrapers is supported above the trough on suitable rollers and brackets.

The chain and scrapers are driven by suitable gearing with speed-cones for regulating the speed at which the scrapers move along the bottom of the trough.

Water is supplied by a centrifugal pump (3 inches in diameter) which gives an ample supply through a valve for regulating the quantity of water supplied to the trough; and an overflow pipe allows any surplus water to run back to the pump. The water is admitted at the upper end of the trough and runs over the scrapers down the trough to the lower end. The scrapers are 4 inches deep and fit the trough accurately at the sides and bottom, the shape of the section of the trough enabling them to maintain this fit, as wear takes place.

A screen of fine mesh is provided at the lower end of the trough to receive and separate the water from the coal.

The coal is conveyed by a horizontal conveyor from the screen, and delivered into an elevator, and is then screened by a vibromotor screen when required.

An iron hopper is provided to receive the coal from the elevator or the vibromotor screen when in use. The hopper is situated above the centre of the washer-trough, and delivers the coal by means of an automatic feed into the trough, midway between its ends, *i.e.*, 30 feet from either end.

The operation of separation by washing is performed on the same principle as that of all other coal-washers, viz.: the difference of the specific gravities of the coal and the dirt. The dirt, being the heavier, sinks to the bottom of the trough, and is caught by the scrapers which

convey it slowly to the upper end of the trough and thence deliver it into a small tram or coal-waggon for removal. The coal being the lightest, sinks more slowly, and is carried away by the water to the lower end of the trough, and thence delivered on to the gauze-screen, which extracts the water from the coal and delivers it into the boot of an elevator which raises it into a storage-box. The storage-box is provided with a hoppered bottom and a sliding door to facilitate the loading of the waggons which run on rails under the storage-box.

The coal is admitted into the trough by means of an automatic feed, which can be regulated so as to admit the proper quantity of coal continuously to the washer. The speed at which the scrapers move along the bottom of the trough towards the top is regulated by means of cone-pulleys on the driving gear, and varies with the quantity of dirt in the coal.

The quantity of water is regulated by means of a valve through which the water is admitted to the trough.

By these combined means of regulation, a wide range of conditions can be complied with, and when once regulated for any kind of coal, needs no further attention. The washer is perfectly automatic in its action; the attendants are required only to see that the supply of coal remains constant, that the washed coal is taken away, and that ordinary attention necessary to any machinery in motion is afforded.

The water which is drained from the coal by means of the moving gauze-screen returns to the pump, which elevates it to the washer, and it is used over and over again. A small supply of fresh water is needed to make good the waste which escapes with the coal and dirt.

The supply of fresh water is admitted in the form of small jets on to the coal as it is passing over the gauze-screen, and serves to brighten and clean the coal before it is elevated into the storage-box.

The quantity of water in circulation is about 150 gallons per minute, and the centrifugal pump is large enough for this purpose.

The whole of the plant is of an extremely simple construction, and the only parts likely to require repairs for a considerable time are the pump and gauze-screen, although if properly attended they cannot give much trouble.

The results of washing the coal at Wirral colliery are as follows:—

The washer was guaranteed to wash 10 tons an hour, but it has been found capable of washing 11 tons an hour.

The amount of ash contained in the slack before washing was 25 per cent., and after washing, analysis showed 4·2 per cent. of ash in the coal,

of which 1·20 per cent. is free dirt and 3 per cent. is natural residue. By examination the coal appears quite free from dirt which could be separated by washing. There are naturally a few pieces of coal which have impurities adherent to them, and not freed by washing.

The dirt appears to be perfectly free from coal, and contains a large percentage of mud, or what would be very fine dirt if dry, which shows that the scrapers form an efficient dam to convey all the dirt to the upper and delivery end.

Before deciding to adopt the Elliott system of washing, it was seen at work dealing with very fine coal, viz., all that would pass through a ¼ inch screen, and the result was equally as good as with larger coal.

The following are analyses of washed coal and dirt from Wirral colliery:—

	Washed Coal. Per Cent.	Dirt from Coal. Per Cent.
Fixed carbon or coke	55·87 ...	8·50
Volatile constituents	38·65 ...	17·20
Ash	4·20 ...	68·75
Sulphur	1·28 ...	5·55
Totals	100·00 ...	100·00

The vibromotor screen (Figs. 8, 9, and 10, Plate VIII.) consists of the application to a useful purpose of a force, which, in most cases where machinery is used, is a great nuisance as well as a source of expense. Few people experience this more than colliery engineers who employ eccentrics or cranks to give a reciprocating motion to heavy coal-screens. The motion is communicated not only to the screens but to the whole of the structure in which they are situated, and the same thing takes place when any part of machinery not well-balanced is moving at any but a very moderate speed. The vibromotor is the application of this force to shake a screen, and consists of a moving part (out of balance) attached to the screen, which is suspended on wire ropes, and the unbalanced part driven by a jointed or flexible rod.

In its simplest form it consists of a spindle revolving in brackets attached to the end of the screen, and having fixed on one end of the spindle a lever or arm with a weight attached at the outer end. The spindle is caused to revolve by means of a jointed or flexible rod.

The weight being on one side of the spindle and centre of movement, and unbalanced by any other weight opposite it, the centrifugal force of the weight pulls the screen with it, and thus causes the screen to make a circular motion with it.

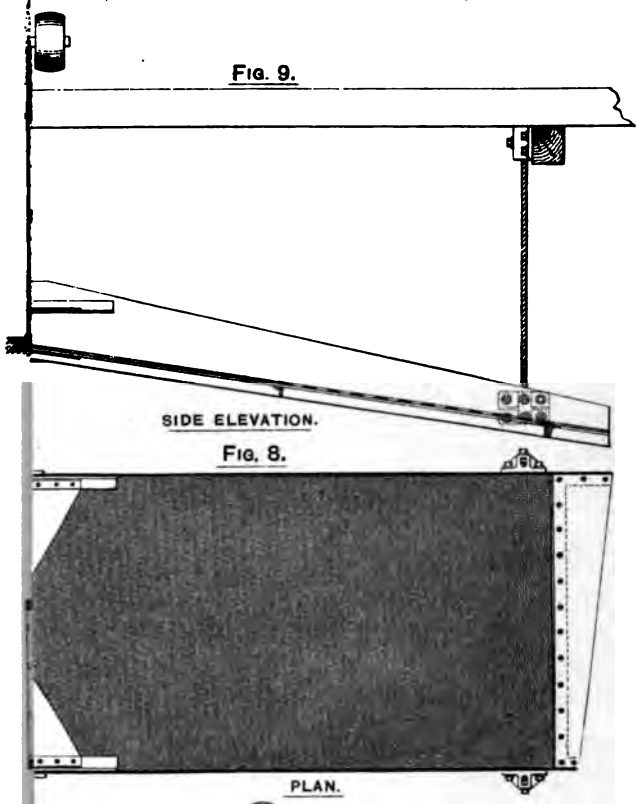


Fig. 9.
SIDE ELEVATION.
Fig. 8.
PLAN.

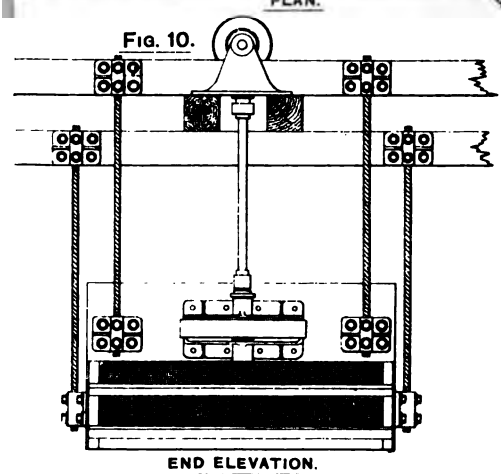
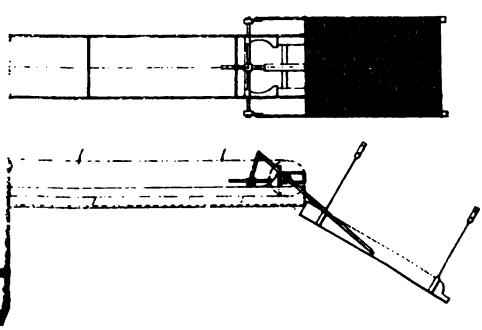


Fig. 10.
END ELEVATION.



When the proper speed is attained, the screen really forms the balancing weight for the weight on the lever, and the two revolve around a centre at a point between the weight on the lever and the spindle which carries it. A scouring motion is thus imparted to the screen without the slightest vibration being communicated to anything else.

The power necessary is that required to cause the spindle and the attached weight to revolve at the required speed, varying from 250 to 350 revolutions per minute.

It would be difficult at Wirral colliery to fix any other screen but a revolving one of the old type, on account of its being placed at the top of the building, which is very slight. A revolving-screen would be more costly, and not so efficient, because only a very small portion of the surface of a revolving screen is effective, whereas in the vibromotor screen the whole of a flat surface is used.

Mr. J. R. Breckon (Sunderland) said that the subject of coal-washing was undoubtedly one of great importance and of deep interest, especially to the colliery owner. The primary object should be thorough efficiency in washing. If the dirt be not entirely removed the machine that may be in use can only be treated as defective. The importance of this opinion may be shown by the following illustration :—A firm manufacturing large quantities of pig-iron were offered a washed coke which contained 91·93 of carbon, and in reply they stated that they did "not buy any coke that contained less than 94 per cent. of carbon." The difference of 2 per cent. in carbon was equal to 6d. per ton on the coke at the place of delivery; the price was 21s. 6d. per ton, half of which was for the coke, and half for carriage, etc. This example shows that efficiency in coal-washing, especially where the coals are required for the manufacture of coke, is of the utmost possible importance. Where coals are to be used for steam boilers and for other heating purposes a little less carbon with 2 or 3 per cent. more of ash is not of so great importance.

With regard to the Elliott washer, it may be at once assumed that by moving the dirt in the opposite direction to the flow of water and of the washed coal, it is an improvement upon the old-fashioned trough-washer, where the coal, the water, and the dirt all moved in the same direction. There is, however, one objection to the Elliott machine, that the action of the scrapers which move along the bottom of the trough tends to mix the dirt with the coal to an objectionable extent. In this

respect, the Murton washer appears to possess a distinct advantage, inasmuch as the refuse is deposited on a series of trays, each about 8 feet in length. The refuse on each tray is not disturbed as in the case of the Elliottt machine, but is carried forward by the travelling-belt, so that each tray finishes its washing, and moves forward leaving the last few trays on the belt containing cleaned coal. The trays are carried to the end of the belt, and the coal is teemed into a receptacle, whence it is sent to the coke-ovens or for other purposes.

The cost of washing the coal is not given in Mr. Platt's paper. In Mr. W. O. Wood's paper on the Murton coal-washer,* the cost of washing is given at 0·76d. per ton, and by means, which are described in the paper, it may be reduced to 0·48d. per ton.

Mr. D. A. Louis (London) said that he had looked through Mr. Platt's paper, but he did not notice any account of practical experiments made with the vibromotor screen. It would be interesting if Mr. Platt could give the dimensions of the vibromotor, the weight, the material with which it was constructed, its capacity, and the horse-power required to drive it. It was stated that the separation took place very rapidly, in fact, within the first foot or so of the screen. That pointed in the direction of making the vibromotor screen very much smaller than the ordinary jigging-screen.

Mr. C. J. Oliver (Chesterfield) asked whether the ¼ inch screen was a bar-screen or a round or square-meshed gauze, as it would make much difference in the size of coal that passed through. As far as he had seen, it was possible to revolve the weight solely of the vibromotor screen, and thus set up a considerable vibration, and if that was so the building would require to be strong enough to resist that motion.

Mr. J. Pearson (Chesterfield) said he would like to ask the writer of this paper whether the Elliott washer had been at work sufficiently long to ascertain the cost of maintenance? He would also like to know whether the water and washed slack were efficiently separated, whether the silt passing through the fine mesh was not a very awkward matter to deal with, and whether the dirt which passes through the end of the washer is largely impregnated with water, and thereby causes much annoyance and trouble? He believed that he had an Elliott washer at work before it was erected at Wirrall colliery. He thought that unless the coal was properly sized, the washing was not very perfect.

Mr. James Platt, replying to the discussion, said that the coal washed at Neston colliery is not used for coking. Analyses of coke

* *Trans. Fed. Inst.*, vol. ix., page 42.

made at the Thornhill collieries, Yorkshire, with unwashed coal and coal washed by the Elliott washing-machine are as follows :—

	Coke made from Unwashed Coal. Per Cent.	Coke made from Washed Coal. Per Cent.
Sulphur	2·93	1·21
Ash	20·26	6·50

The cost of washing was about $\frac{1}{8}$d. per ton. The Elliott washer at Neston has not been in work long enough to afford sufficient information as to the cost of repairs, but judging from the construction of the machine, and its easy, slow-moving parts it could only be nominal. The cost of the complete plant, including house and storage-boxes, was £730. The capacity of the plant is being now doubled, at an additional cost of £260. The term "natural residue" was applied to the natural ash of the pure coal, which cannot be separated by washing or any other means.

The dimensions of the vibromotor were 4 feet wide by 6 feet long, and it weighed 3½ cwts. The horse-power required to drive the vibromotor is small, but the belt used to drive it is capable of transmitting 2 horse-power. The capacity of the screen depends upon the size of mesh used, but the screen, as now fitted with a perforated sheet with $\frac{7}{8}$ inch round holes, at present deals with 125 tons per day of 10 hours, and is capable of dealing with 250 tons per day when required. Vibration in actual practice is not communicated to any part of the building, only to the screen itself. Mr. Louis remarked that the statement that the separation took place very rapidly pointed in the direction of making the vibromotor screen much smaller. This is the case, but it will be seen that it was provided to deal with double the quantity now passing over it, and also for various sized meshes. There is no doubt that the vibromotor screen can be made shorter than any reciprocating screen to deal with the same quantity of coal.

The Elliott washer at another colliery has been at work much longer than the one at Neston colliery, and Mr. Pearson should be better able to arrive at the cost of maintenance than the writer. The water and washed slack are efficiently separated, the silt is easily dealt with, and the dirt at the end of the washer contains very little water. The bulk of the coal washed at Neston colliery is washed without being sized by the vibromotor screen, and the results, recorded in this paper, are obtained from such coal.

The CHAIRMAN moved a vote of thanks to Mr. Platt for his paper.

Mr. EMERSON BAINBRIDGE read a paper on the "Vibromotor."

DISCUSSION UPON MR. WINKHAUS' PAPER ON "THE BLASTING EFFICIENCY OF EXPLOSIVES."*

Mr. DEACON said that Mr. Winkhaus' paper would have been more interesting to English mining engineers if some of the explosives more generally used in England had been introduced into the tests; and if, further, the results of the explosive power of blasting-powder had been compared with those of the high explosives. He would also like to know from Mr. Winkhaus whether the shattering effects of the high explosives had been observed when used in coal, and how the results compared with the effect in the same coal when blown by blasting-powder. He (Mr. Deacon) said that, for the purpose of blasting stone or bind, there could be no possible doubt as to the superiority of some of the high explosives over blasting-powder, both in the matter of safety and economy. What he wanted to discover was an explosive combining the safety of the best high explosives with the slowness of action of blasting-powder. When such an explosive was discovered, he thought that there would be little objection to the abandonment of the general use of blasting-powder in coal-mines.

Mr. WINKHAUS, replying to Mr. Deacon's observations, said that it was impossible by the leaden cylinder test to compare the explosive power of high explosives with those of blasting-powder, as he had previously pointed out in his paper on the subject. In his (Mr. Winkhaus') opinion no judgment can be formed except that based upon experience in practical mining. As to the effect obtained in mining coal with high explosives in Westphalia they were well satisfied with their use, although the results were not equal to those of blasting-powder under all circumstances and in all seams. In this, however, he agreed with Mr. Deacon that it would be desirable to use an explosive combining the safety of the best safety-explosives and the slow action of blasting-powder.

DISCUSSION ON MR. E. THOMPSON'S PAPER ON "THE USE OF STEEL GIRDERS IN MINES."†

Mr. E. THOMPSON, referring to Mr. Wain's suggestion of using girders, with a breadth of flange equal to the depth, said that the extremities of the flanges of such sections are too far from the support of the web to add materially to the strength of the girder, whilst the

* *Trans. Fed. Inst.*, vol. x., page 264. † *Ibid.*, vol. x., page 272.

increased weight would materially add to the cost. The advantage would only apply to the lengths of 6 inches at each end, where the bar rests upon the prop, and probably an iron plate, 6 or 7 inches wide, bolted to the girder, would give equally satisfactory results. It is worthy of notice, that a wooden lid placed on the top of a wooden prop, at right-angles with the bar, forms an excellent cushion, and lessens the liability of splitting the prop.

No experiments had been made by the writer (Mr. Thompson), but the gain in strength claimed by securing the ends of a girder is generally admitted, and is illustrated by the fact that the curve which is formed by a load in the middle of a girder, simply resting upon end-supports, is lessened when the ends are firmly secured ; for the action of the corresponding counter-bends that are formed tends to distribute the strain more uniformly along the whole length of the girder, and the stress at the centre is equal to one-half of that in a girder where the ends are loose.

Girders used as props in gateways, or at the face of the workings, are found in some mines to be equally serviceable as when used for bars, provided that they are made with flat ends. If set in the usual form, the sharp end of the girder destroys a great number of lids, and quickly cuts into the floor and roof. A steel girder-prop, with flat ends, has been found to last as long as thirty wooden props, and it is quite possible that under some conditions this number would be exceeded. In comparing the first costs, the difference is much greater than in the case of bars, as the class of timber used is lighter and cheaper than larch, but the number of wooden props that are broken is so great that the strength and durability of the steel girder more than compensates for the additional outlay.

Steel props are heavier, but the additional safety should counterbalance this objection with those who use them. A certain amount of elasticity is provided by setting the steel props with a wooden lid, both at the top and bottom, and a supply of these, of various thicknesses, quickly meets any slight variation that may occur in the height of the seam. A hole is punched in the web of the prop, into which a hook attached to a chain is inserted when the prop is to be drawn.

Mr. HARGRAVE WALTERS read the following paper on the "Lead and Lap of Winding and Other Engines":—

LEAD AND LAP OF WINDING AND OTHER ENGINES.

By HARGRAVE WALTERS.

The able and instructive paper contributed by Mr. Maurice Deacon on "The Use of Expansion-gear as applied to Colliery Engines," * leaves but little new ground to travel over in explaining the governing principles of winding-engines, and the advantages of the various fuel-saving appliances by means of expansion-valve gearing, etc., more particularly in connexion with Cornish valves. Possibly the subject-matter of this paper might have been of more value could it have been introduced into the discussions on Mr. Deacon's paper. The principal point that is now being brought forward, however, was not quite sufficiently developed at that time, although the subject had occupied the writer's mind for some years, and had been satisfactorily experimented upon during the last two years.

The writer's earliest recollections are associated with atmospheric winding-engines, with large vertical cylinders and beam, of condensing and non-condensing types fitted with Cornish valves—almost invariably in use at that time.

The slide-valve was not generally used, as now. Efforts have been made, for some years, to produce a balanced slide-valve that could be substituted for the easy-working Cornish valve—not however with sufficient success to recommend its use in large winding-engines. Such a valve, it is well known, would be of the utmost value, on account of its adaptability in giving lead and lap in the admission, letting out, and cutting-off expansively of steam, to suit all degrees of work that an engine may be required to do—a point in which the Cornish valve is not so successful.

The heavy ponderous exhausting-gear of large non-condensing engines (with the necessary Cornish valves) and sluggish movement in starting under load have been the characteristic defects of such engines generally, and led to the adoption of the balance-drum and weight, and other modern devices. The balance is a valuable adjunct in giving life to the working load, and is a step in the direction of economy. It is, however, deplorable

* *Trans. Fed. Inst.*, vol. vii., page 672.

that these things are in very many instances left unimproved; probably the engine might be made to do much more work, if some system of cut-off, or variable, or proper lead, were applied to the valves) either Cornish or slide-valve) and by such means lessen the waste of fuel and boiler-plant so well described by Mr. Maurice Deacon.

The importance and usefulness of any system of expansive cut-off, applied more particularly to winding-engines is at least seriously curtailed; and in some instances much money is wasted—in attendant expenses consequent upon the substituting of boilers to work at much higher pressure—without the means of giving, at the same time a proper, simple and definite lead—just as it may be required to suit the variation of the load.

It is well known that a coupled winding-engine, of necessity, must be worked by link-motion, and, in the case of Cornish valves, to keep the engine under proper control at any time, the valves should be closed. Under these conditions, there is no opportunity of affording lead, as, under the best possible circumstances steam could not be discharged, or admitted again, until the piston had made a full stroke, in which case it would necessarily, to some degree, butt the steam to be exhausted before it could be relieved; and the ingoing steam entering late, there being no opportunity of admitting it so as to be ready for its work at the proper moment on the return stroke, also of cushioning, *i.e.*, compression giving an almost noiseless and safer effect to the heavier working portions of the engine. The necessity for lead in the first strokes of a winding is of little or no importance, but as the speed increases such an application then becomes necessary.

To accomplish this object effectually, the eccentrics must be capable of being moved on the shaft, forward and backward, at will, at any time while the engine is in motion. This Mr. Thornley and the writer have been able to do, in the most direct and simple way, in the manner described in the accompanying drawing (Figs. 1 to 7), a method equally applicable to almost every class of steam-engine, but more especially to winding and hauling-engines, working under variable conditions. The following is a description of the invention :—The engine-shaft *A*, or a secondary shaft *B*, sliding on the shaft *A*, moves the lever *C*, carried on a stud *D*, fixed on and driven by the shaft *A*. The lever *C* operates on the eccentrics *E*, moving them round the shaft *A* inversely: thus giving the necessary lead to the valves, as shown by the dotted lines (Fig. 2). The sleeve *B* is moved by a forked lever and a light shaft, placed conveniently

to the engineman, and worked either by a treadle or a hand-lever, or automatically, if desired.

This arrangement is suitable for engines fitted with single eccentric, or single and coupled link-motion.

A few cases may be described, in which a means of giving variable lead is an absolute necessity for the proper working of an engine, under varying conditions and speeds.

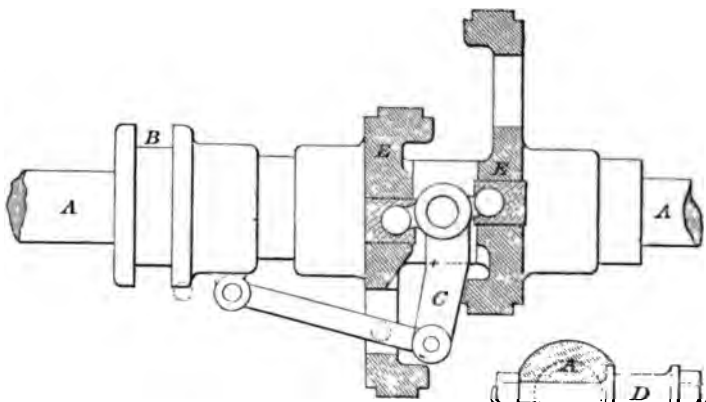


FIG. 1.

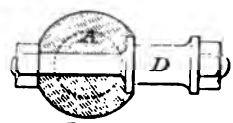


FIG. 3.

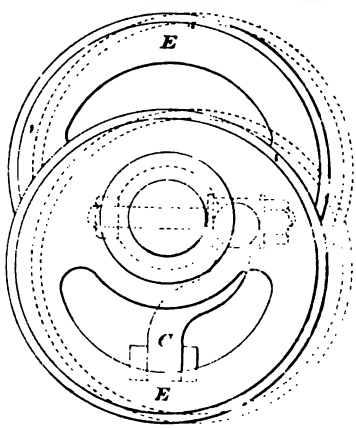


FIG. 2.

FIG. 4.

FIG. 5.

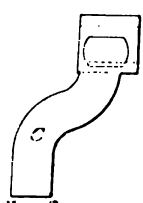


FIG. 6.

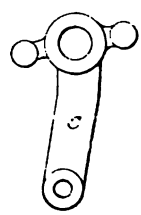


FIG. 7.

Take the case of a hauling-engine, with drums on the engine-shaft, drawing trains of thirty-five tubs on an engine-plane, 8,400 feet long, inclination 1 in 11, required to supply its share of the output to the shaft-bottom. These engines, without any fly-wheel, must begin from a mere crawl out of the level-slopes increasing in speed to 100 or 120 revolutions per minute. To take hold of the train easily and safely only a limited amount of lap or lead of the valve can be allowed, if the

hauling-engine is to be kept under proper control: an indicator-diagram taken at this initial point is what it should be to start with, but as speed is gained an efficient diagram and proper efficiency of working is simply out of the question. The only method adopted, so far, to obtain economy under such circumstances is to notch up the reversing-lever, which, however, means wire-drawing the steam, and does not improve the speed of the train, in fact it has as a rule a contrary effect where the engine is pressed. In this instance, there should be means of giving variable lead, at will, to the valves, and the slide-valve shows to the best advantage, for it not only gives lead in the admission of steam, but, as is well known, it also gives at the same time a corresponding lead in letting out the exhaust steam. It may be urged that, in such cases, the addition of a cut-off valve operated at will would meet the case. This addition is most valuable, but it is only of very secondary importance unless the main-valve be working under proper conditions.

In the case of a large Waddle fan, driven by a cylinder 30 inches in diameter and 42 inches stroke, in order to meet the exigencies of the mine it became necessary to increase the speed from 35 to 65 revolutions per minute, and to keep up this speed with anything like fair results with a steam pressure varying from 36 to 44 lbs. per square inch (generally 38 lbs.) both main and cut-off valves required setting fairly well. The ports were of large capacity, the valve-stroke or travel was $6\frac{1}{2}$ inches, with an adjustable cut-off valve, which may be said to be all that is desirable in these respects. In actual experiments at 35 revolutions per minute, the main-valve at a lead of $\frac{5}{16}$ inch gave a good admission or compression curve on an indicator-diagram, and an easy and quiet motion to the engine; at 65 revolutions per minute, to produce a similar diagram, in admitting steam, a lead of $\frac{5}{8}$ inch in the main-valve was required. At this point, it may be mentioned that no engineer at the present time would attempt to run an engine under any other conditions. It is, however, an undoubted fact that lead and proper adjustment of the valves with regard to the admission of steam and exit of the exhaust-steam at the proper time is very much overlooked, and especially where a cut-off valve is in use, as it is too often thought to embrace all that is necessary, while its real value is destroyed by the neglect of its more important companion-valve.

In the following instance, a winding-engine, attached to a pit about 600 feet deep, was used for lowering and raising workmen. The slide-valves were set to suit the load starting from the bottom of the shaft, and gave a good indicator-diagram when running at a speed varying

from 20 to 30 revolutions per minute. It became necessary to make the winding in about 30 seconds, consequently the winding-engine had to attain a speed of at least 60 revolutions per minute. Under the new conditions, from a very fair diagram, and an absence of back pressure, a wretched diagram was drawn, the steam admission was bad, and the back pressure of steam was at least 10 pounds per square inch. It was thought that this loss might be obviated, to some extent, by halving the lap and lead of the valves, but the change, when made, operated against starting and getting the load away from the bottom of the shaft, and the valve was consequently restored to its original position. This was another case where the means of giving variable lead at will to the slide-valve would show itself to advantage.

It may be of some service to the members to say a few words on the application of reduced lap and lead to the slide-valves of a locomotive used for shunting purposes. As a rule, locomotives used for shunting and work of a similar character are fitted with valves with lap and lead of the usual formula, where speed is really not required, as if intended to run at a high speed. For such use, the lead of the valve should be very limited, and the lap reduced in similar proportion; and much better results would be obtained if the valves required were made, and the eccentrics set, to suit the work that the engine was required to perform.

In conclusion, much of what is written in this paper may be well known to a number of the members, but the writer's object was to bring the subject before the younger and less experienced members.

Mr. MAURICE DEACON (Alfreton) considered that the Thornley-Walters arrangement, as explained in the paper, might, in certain cases, be of advantage in the economizing of steam. He thought, however, that where an engine was so designed as to perform the work which it ultimately had to do, the addition of automatic expansion-gear would do the work better than the arrangement suggested. But where an engine had been designed for a certain amount of work and it was required to do double that amount of work (as the writer instanced in the case of a fan engine, which was running at 35 revolutions per minute, and which was required to increase to 65) the design of valves and levers in the arrangement before them might be useful. There was one objection, however,

that was the control of the engineman. There was always an objection to giving an engineman more to do than was absolutely necessary for the ordinary controlling of his engine. In the first place, his whole attention should be concentrated on the ordinary work of attending to his engine, and, in the second place, they could not always rely on the attention of the engineman, which was necessary for an appliance of that sort He suggested that it might be made to work automatically, which would overcome this objection. In the foregoing reference to the use of expansion-gear it was necessary to assume that the steam pressure was sufficiently high to enable the expansion-gear to work with economy. If it was low it could not be worked with economy; but if the steam pressure was sufficiently high, he was of opinion that automatic expansion-gear would fulfil all the functions for which that apparatus was designed just as well as the Thornley-Walters apparatus.

Mr. T. M. Favell (Stoke-upon-Trent) said that the design for altering the lead on the valves of engines, described by Mr. Walters, appeared to be quite correct in principle, but he would like to know how long it had been at work. There would, he feared, be soon a good deal of play caused by the wearing of the various moving parts, and the proposal to put it into gear by and at the will of the engineman was, he thought, not very good. An engineman attending to a winding-engine had quite enough to do without giving him a cut-off or similar gear to put in action with either lever or screw, as mentioned in the paper. The chances are that in this case it would not often get put into gear. The only proper way, in his opinion, was to do it automatically, so as to ensure its constant and proper use.

The winding-engine being an engine running at a variable speed, the design for absolute correct running requires the lead of the valve to be altered, as in a very slow-running engine no lead is best, and in a quick-running one a considerable amount of lead is required. But for the greater part of the time it is fast-running: this requires a considerable amount of lead, and yet in the frequent starting and reversals which have to be made it is necessary to have but little lead to ensure this being done quickly.

He hoped to have seen indicator-diagrams of the working of this valve showing the running of the engine with the gear in and out of action. The members would then be better able to judge of its advantages. Mr. Walters had quoted a few cases in which he states that this gear would be of advantage. In the case of the hauling-engine it might be useful, but

if in making this engine the practice of the best locomotive makers be followed, he thought that no difficulties would be experienced, and good economical results would be obtained. Of course, if the steam pressure was very low in the case referred to, this gear would be useful, but if high, a good result in practice could be obtained by linking up, probably just as good as by a separate cut-off valve, and much easier in its application. The action of a hauling-engine was very much the same as in a locomotive.

In the case of the fan-engine, the speed had to be nearly doubled, and of course what was right for 35 was wrong for 65 revolutions per minute. A much simpler mode of improving this engine would be by taking out the key of the eccentric, altering to the estimated correct position, and fixing it with a set pin, then trying it, and when found correct, cutting a new keyway for this position of the eccentric. This might not be very scientific, but it was very good practice, and he certainly did not think anyone would apply the Thornley-Walters gear on the chance of some years after having to run the engine at a greater but a regular speed.

In the case of the winding-engine, the speed again had to be doubled, and the working was found to be very bad; but all the statements of Mr. Walters point in the direction of the engine having been designed for one speed, and both exhaust and steam pipes and passages which were perhaps all right for 30 being wrong for 60 revolutions per minute. The back pressure and action described point to throttling in the passages. He could not see, if this were the case, that the altering of the lead by the gear would be of much, or any, advantage.

Mr. Walters says that "the importance and usefulness of any system of expansive cut-off, applied more particularly to winding-engines, is at least seriously curtailed, and, in some instances, much money is wasted, in attendant expenses consequent upon the substituting of boilers to work at much higher pressure, without the means of giving, at the same time, a proper, simple, and definite lead, just as it may be required to suit the variations of the load." In this he did not agree with him, as he had found—from the diagrams taken from the winding-engine at the Sneyd colliery, Burslem, an engine fitted with the Woodworth automatic and progressive cut-off gear—that after about 4 revolutions had been made and the cut-off brought into action, only two-thirds of the horse-power used at the starting was necessary, and that near the termination of the run only one-third was required. Now, if the pressure of the steam was sufficient (whatever the initial pressure might be) to start the engine, it was certainly high enough to render a cut-off gear useful, and this

without altering the pressure on the boilers. The fact was that in most cases this requisite reduction in power during the course of a single winding was obtained by throttling the steam.

Mr. Walters refers to Mr. Deacon's paper on "The Use of Expansion-gear as applied to Colliery Engines."* In that paper all the gears except, he thought, one, were brought into action by the use of a governor dependent on the speed of the engine. He thought that this mode of action was wrong, and that a certain position of the cages in the shaft was the proper time for bringing cut-off gear into action, and this without relation to the speed at which the wind was being made. There are cases where the gear described by Mr. Walters would be of use, but he considered it would not be so to quite the extent that the author seems to anticipate.

Mr. C. C. LEACH (Seghill) said he had found that neither exhaust nor steam-valves required any alteration whatever. The valves on the Seghill fan engine had had no alteration, although the power and speed varied considerably. At 20 revolutions per minute, the horse-power (the diameter of the cylinder is 16 inches) was 6·46; at 40 revolutions, 29·61 horse-power; at 60 revolutions, 96·11 horse-power; at 60 revolutions (with separation-door opened), 154·35 horse-power; and at 67 revolutions (with separation-door opened), 209·20 horse-power. Yet they had no knocking and no back pressure above 1 lb. The speed was altered by the governor being weighted for various speeds, and it tripped off the valves instantaneously when enough steam had been admitted for the speed. He noticed that according to these diagrams, the steam pressure averaged on the piston 25 lbs., but in this case they worked at 100 lbs., and got 94 lbs. on the piston at all speeds. He did not believe in any governing that depended on the engineman, nor in one that wire-draws the steam. The full pressure of steam should be admitted to the piston. He had a similar engine working rope-haulage, and there the horse-power varied from 80 to 145, and the valves were never touched by the engineman. It worked perfectly, smoothly, and satisfactorily, although it had only one cylinder and a small fly-wheel, to help the engine over the dead centres. He had also an endless rope-haulage, where the horse-power of the engine varied from 5·74 to 30. They, however, found no inconvenience, although they never touched the valves of the engine.

Mr. F. S. PANTON (Sunderland) wrote that, so far as the utility of the Thornley-Walters arrangement itself is concerned, it might perhaps

* *Trans. Fed. Inst.*, vol. vii., page 672.

be applied with success in the case of a hauling-engine where the gear is not of large proportions, or even in the case of a winding-engine where the eccentrics are outside of the cylinders, and actuated by a trail-crank or arm connected to the crank-pin of the engine, but it would be unsuitable for a winding-engine with the eccentrics placed between the cylinders, because the drum-shaft would have to be made longer, in order to make room for the secondary sliding-shafts or sleeves *B*, and this in the case of large winding-engines would materially add to the cost. The arrangement is also open to the same objection as expansion-gear under the control of the engineman. He (the engineman) cannot be depended upon always to work the operating lever when required, and in fast-running engines he has quite enough to do, without adding to his duties. He would beg to refer Mr. Walters to a description of the winding-engines at Silksworth colliery, in Mr. Daglish's paper on "The Expansion and Counter-balancing of Winding-engines,"* from which an almost perfect diagram is obtained. Since this paper was written a governor has been added to the Silksworth winding-engine, and wedges have been substituted for the set-screws on the tappets connected with the governor, thus varying the amount of expansion in proportion to the load, an arrangement which works most satisfactorily. The winding-engine at Silksworth colliery has two cylinders, 48 inches in diameter, fitted with Cornish valves, and it is winding from a depth of 1,776 feet in 45 seconds. A second winding-engine has been erected almost identical with the first, fitted with a scroll drum. The exhaust-valves were increased in diameter, thus doing away entirely with the small amount of back pressure observable in the diagrams published with Mr. Daglish's paper.

Mr. JOHN HEATH (Burslem) said that the Thornley-Walters gear was of great importance as applied to winding and locomotive engines, and in all other cases where an engine had to move heavy loads from a state of rest to a considerable velocity in a short interval of time. There have been many attempts to attain the same object, but the one under notice is a very simple contrivance, and should come into general use. When live steam can be admitted and exhaust steam liberated earlier in the stroke, as the speed of the engine increases, the back pressure is reduced to a minimum, and steam economized to the extent of 10 to 20 per cent. This is a question worthy of serious consideration, and will result in many advantages. The engine will move more freely and make less noise by the sudden action of the steam on the piston at each stroke, and there will be less wear-and-tear with a higher duty

* *Trans. N.E. Inst.*, vol. xxv., page 201.

for the same plant and machinery. The efficiency of the engine (in the case of winding) would be much greater if, in addition to the above, there was provision made for a cut-off valve. A cut-off valve that reduces the consumption of steam by about 20 per cent. has been applied to a winding-engine, with cylinders 36 inches in diameter, and it works more freely than before with this reduced consumption of steam. The cut-off gear comes into operation after the second stroke, and accelerates as the winding increases up to within the last three strokes, when it falls out of gear. It works automatically, and requires no attention from the engineman whilst winding.

Mr. B. WOODWORTH (Fenton, Staffordshire) wrote that the arrangement described by Mr. Walters is ingenious, and would improve the working of an engine arranged to give steam-admission for the full stroke with the ordinary gear. Whether it would be a practical success in working requires fully testing, and he thought that it would be subject to heavy wear-and-tear and soon be far from noiseless in its action. In very few cases would it be convenient to attach the gear to existing engines, and the fact of it having to be put in and out of action by the engineman would prohibit its adoption where quick winding is necessary. As regards the efficiency of balanced slide-valves for large winding-engines, he thought that North Staffordshire had proved their practicability: there are over twelve large winding-engines (principally with cylinders 36 inches in diameter) of that class in the district, with a working experience spreading over from three to twenty years, and he might safely say that in no case had there been any wish to go back to the Cornish valve. He did not agree with Mr. Walters' theory that the Cornish valve is less adapted for working expansively in a winding-engine than the slide-valve is, and either can be adjusted within certain limits very effectively. The Cornish valve and gear, in addition to being more costly, has also much more wear-and-tear than a good slide-valve and gear, and puts more angles in the passage-flow of the steam to and from the cylinders. With suitable arrangements and proportions, none of the sluggish movements spoken of in Mr. Walters' paper are apparent in their working, and, in fact, their particular advocates have generally been free with claims to the exact contrary.

Balance-rope arrangements give very great advantages, as they enable the speed of winding to be attained much more quickly and maintained till nearer the end of the winding than is practicable in the ordinary way of working. He would like to see a deep winding-shaft fitted with a modified system that was applicable to winding with ropes in separate

shafts, flat-rope systems, or unequal winding from two ropes in one or two shafts, and left the sump arrangements as clear as in the ordinary system; consequently, there was considerably more room for working than is permissible with the ordinary Koepe or bottom-balance rope-systems, and it is equally advantageous in use.

He thought that Mr. Walters was strongly imbued with the old but very prevalent idea that a winding-engine must be arranged to take steam for the full stroke for starting purposes. This view, in his opinion, was to a very great extent the cause of winding-engines being such extravagant steam-consumers, as although the range of expansion with the main valves of winding-engines is but a limited one, yet it is a potent factor for economy and efficiency, and when properly applied generally gives an increase of power and speed of working along with the economy. He would no more think of erecting a haulage-engine without a fly-wheel or its equivalent than he would put in the valve-gear to give admission of steam for the full stroke to either hauling or winding-engines.

Mr. H. WALTERS, replying to the discussion, said that his paper dealt more, probably, with engines which were not altogether designed for the work they had to perform. Mr. Deacon was altogether wrong in supposing that expansion-gear would perform the same functions as the eccentric gear. With regard to operating the gear automatically, it is quite a matter of choice; the writer would always endorse anything that would minimize the winding engineman's duties. He did not propose that the gearing should be applied to fan-engines.

The gear had just been attached to an engine in order that it might be exhibited to the members, but the principle, in a crude form, had been tried for more than a year upon a winding-engine, with cylinders 30 inches in diameter, with excellent results. There are only two working parts practically, and there is little movement in any part. The engine specially referred to has ample steam and exhaust ports for speeds much higher than it could possibly be required to run. The eccentric gear can be shifted under full steam with little or no perceptible difference in weight.

The Thornley-Walters gear is not intended to compete with trip cut-off, or any expansion-gear, but simply affords a means of giving lead as a valuable adjunct in connexion with such gearing and with the variable work of an engine. The writer agrees with Mr. Leach's remarks on wire-drawing steam and as to full admission of steam to the pistons, and congratulates him on having so efficiently equipped Seghill colliery with steam-power.

There is no difficulty or excessive expense incurred in applying the eccentric shifting-gear to any sized engine or to the class of engine Mr. Panton referred to. By using a secondary shaft and small eccentrics, there is certainly no necessity to lengthen the drum-shaft, or to place the cylinders further apart, or to reduce the width of the drum, and the link and valve motion need not be disturbed.

The writer notes with great satisfaction Mr. Heath's remarks, and agrees with him that an expansive cut-off is necessary for the economical working of engines. The eccentric shifting-gear is really meant to assist in further improving engines that are working under less favourable conditions.

The PRESIDENT proposed a vote of thanks to Mr. Walters for his paper, which was adopted.

Mr. SOPWITH proposed that a cordial vote of thanks be given to the authorities of Firth College for the use of their rooms for the meeting that day; to the owners of collieries and works which they were allowed to visit that afternoon and the following day; and also to the local committee of the Chesterfield and Midland Counties Institution of Engineers, who had taken considerable trouble to make that meeting a success.

Mr. G. LEWIS seconded the resolution, which was approved.

Mr. J. A. LONGDEN proposed a vote of thanks to the President, who briefly replied.

The meeting then terminated.

The following notes record some of the features of interest seen by visitors to collieries, works, etc., which were, by kind permission of the owners, open for inspection during the course of the Sheffield meeting, on February 19th and 20th, 1896 :—

MESSRS. W. JESSOP & SONS, LIMITED, BRIGHTSIDE, SHEFFIELD.

The process of welding by the deflected arc system was shown in operation.*

MESSRS. JOSEPH RODGERS & SONS, LIMITED, SHEFFIELD.

The members were conducted through the works by the various managers of departments, and shown the forging of table cutlery, hardening, tempering, tanging, and grinding; also the hafting in ivory, horn, wood, etc.; pocket-knife blade forging, grinding, and the making of the springs, and the cutler or maker up of the complete knife; razor-grinding and hafting. The ivory warehouse was shown, where elephant tusks of all sizes were stored by the ton—kept ready for the cutting-room, in which were seen the workmen cutting for all the various kinds and sizes of handles and scales. The show-rooms contained examples of the finished goods, also many exhibition knives, scissors, razors, etc.

MESSRS. WALKER & HALL'S ELECTRO WORKS, SHEFFIELD.

The visitors inspected the following rooms and departments, viz., show-room, repair-warehouse, warehouse for plated goods for dealers, burnishing-rooms, silversmiths' shops and silver and soldering-rooms, chasers' room, saw-piercers' and punching-room, sterling silver work-shop, glass-room, table-knife cutlers' shop, spoon-and-fork buffing-rooms, die-sinkers' room, silver-finishing room, white alloy-goods buffing-room, knife-handle, ferrule, and nut-cracker workshop, ivory-and-pearl carving shop, etc., silversmiths' turning and spinning room, hollow-ware warehouse, designers' and modellers' room, engraving-rooms, plating-rooms, punching and stamping-shop, draughting and pressing-shop, table-blade forgers' shop, blade-grinders' wheel, pneumatic hammer and wheeling shop, spinning shop, engineers' machine-shop, figure-casting shop, nickel-silver ingot-casting furnace, etc.

---

* *Trans. Fed. Inst.*, vol. xi., page 40.

MESSRS. WM. HUTTON & SONS, LIMITED, SHEFFIELD.

The members viewed the show-room containing every class of silversmiths' work, passed to the designing-room, where the modelling of figures and examples of art work were inspected, and thence through the offices into the factory, where they saw the casting of nickel or German-silver into ingots ready for rolling into sheets for making spoons, forks, hollow ware, etc., and through the various stages of manufacture of spoons and forks by machinery. A powerful drawing press for producing entrée-dishes, cups, etc., was seen at work. The plating department was visited, where the depositing of silver and gold was in process. The manufacture of coffee-sets, trays, etc., in nickel silver and sterling silver, and the various methods of ornamenting the same by chasing and engraving were also viewed. A visit to the warehouses, containing silver, hollow ware, and cutlery concluded the visit.

FIRTH COLLEGE, SHEFFIELD.

Firth College is one of the ten English provincial university colleges. Steps are now in progress to incorporate it, with the Technical and Medical Schools, into a larger university college, and to seek incorporation with the Victoria University. The departments of arts and pure science are located in the present Firth College; but new buildings are being erected opposite the college for arts. The Medical School is across the road, while the Technical School is in St. George's Square, about five minutes' distant. Amongst the matters of chief interest to the members of The Federated Institution of Mining Engineers may be mentioned the department of mining and the Technical School. The Mining School is one of the largest in the provinces, more than 70 students attending on Saturdays, the course extending over two years. In addition, similar centres are carried on by the college at Derby for the Derby County Council, and at Barnsley in conjunction with the Yorkshire College for the West Riding County Council. The college inspects the local classes in coal-mining held in connexion with the Derbyshire County Council, and itself carries out a system of peripatetic lectures in the West Riding. A new departure is under consideration whereby the curriculum may be much extended and metalliferous mining taken up, and the students divide their work between the college and work at the mines.

THE SHEFFIELD TECHNICAL SCHOOL, SHEFFIELD.

The Sheffield Technical School has day and evening departments and provides courses of instruction in engineering and the metallurgy of iron and steel.

Engineering Department.—In connexion with this department there is a laboratory equipped with a vertical tubular steel boiler, working at a pressure of 100 lbs. per square inch, and a compound steam-engine, capable of indicating 50 horse-power, fitted with surface and jet-condensers, brakes, indicator-gear, gauges, measuring-tanks, etc., and designed to work under a variety of conditions, for illustrating steam-engine economy. There is also a gas engine, a 50 tons testing-machine, a hydraulic pump and accumulator, and dynamometers, indicators, pyrometers, draught-gauges, oil-tester, etc. A machine and fitting-shop, wood-working department, and smiths' shop, contain all necessary shop and bench tools and appliances. The large physical laboratory fitted up with all necessary appliances for practical electrical work and the large drawing offices are also in connexion with this department.

Metallurgical Department.—This, the distinctive feature of the Sheffield Technical School, is principally carried on in a building equipped with a 25 cwts. open-hearth steel furnace, with three systems of gas-producing (viz., ordinary, oil, and water-gas), hydraulic cranes, forced-draught appliances, and falling weight test. A crucible steel-house with two melting-holes, and a pot-house with pot-making tools, are situated in a separate small building. There is a flame-and-ore annealing furnace for the production of malleable-iron castings, and a complete iron foundry, equipped with belted cupola, drying stove, and all the appliances necessary for the production of green and dry-sand castings in iron and steel, and also an assay laboratory, and an iron-and-steel laboratory fitted up with all the necessary apparatus for rapidly carrying out tests. The steel furnace was designed with the object of combining in a compact form the ideal requirements for satisfying the fullest measure of efficiency. Special apertures are provided at various portions of the furnace in order to test the temperature, to aspire the gases for analysis to ascertain the progress of combustion and decarbonization, and to test the light of combustion and effect of oxidation spectroscopically. The aim in designing the gaseous fuel generating-plant was to provide means for generating the various characters of useful combustible gases from solid and liquid hydrocarbons, so that the

student may be able to study the respective advantages and disadvantages of each, chemically and otherwise. The plant also serves to demonstrate the chemical and physical actions involved in the cycles of production, and permits of the following combustible gases being generated:—(*a*) water-gas; (*b*) oil-enriched water-gas; (*c*) oil-gas; (*d*) carbon monoxide, or ordinary producer-gas; and (*e*) any mixture of these gases.

NUNNERY COLLIERIES.

The silkstone winding-engine has cylinders each 30 inches in diameter and 5 feet stroke, working a rope-drum, 18 feet in diameter. The parkgate winding-engine has two cylinders, each 24 inches in diameter, and 4 feet stroke, working a drum 16 feet in diameter. A special appliance for signalling in the winding-engine house indicates to the eye of the engineman how many raps have taken place.

The winding-engine at the new pit has two horizontal cylinders, 32 inches in diameter by 6 feet stroke; the Cornish valves are fitted with the Thornewill & Warham automatic cut-off. The drum is of cone-shape to compensate in some measure for the variable load, and provision has been made for suspending a counter-balance rope below the cages. These engines were designed to raise 1,800 tons per day of nine hours from a depth of 900 feet.

The shaft-guides at the old pits consist of steel rails, which are twice the cost of ropes in the first instance, the advantage of their use being that the cages can be brought closer together. Rope guides are used at the new pit.

The haulage in the silkstone coal-seam is performed by a head-rope 11,000 feet in length, which works an inbye incline, bringing 42 tubs, containing 21 tons of coal, up a gradient of 1 in 7 at the steepest part to a point 1 mile distant from the shaft, whence they are brought by a main-and-tail rope engine to the pit-bottom.

Both of the hauling-engines are worked without spur-gear, and the single-rope engine is condensing and is fitted with clutch-gear. Both engines have two cylinders, each 24 inches in diameter, and are erected on the surface, the ropes running down the shaft in pipes.

An endless-rope, 19,000 feet long, is used in the parkgate coal-seam for working the haulage. In the east parkgate district, another endless-rope, 9,600 feet in length, is used for the combined purpose of hauling and pumping. Two pumps are worked by means of this rope; the pumps are

three-throw plunger-pumps, geared to 5 feet driving pulleys, fixed vertically. The pumps are each capable of pumping 50 gallons per minute.

Two endless-ropes are used upon the surface for the purpose of hauling the new silkstone and the parkgate coal to the main heapstead, and carrying dirt, etc., to the spoil-heap. These ropes are each about 2,700 feet in length, and are driven by two pulleys having five and four grooves respectively.

The pumping at the colliery is very heavy, power being provided for raising 6,000 gallons of water per minute. A large Cornish beam-engine with a cylinder 86 inches in diameter and 10 feet stroke is kept constantly at work.

Three duplicate horizontal, direct-acting, compound pumping-engines are placed underground. They are fitted with rams, 15 inches in diameter, and are each capable of pumping 1,000 gallons of water per minute.

There are nine Lancashire boilers fitted with the Proctor mechanical stoker, which enables inferior coal to be used for firing.

The Arnold boiler, 30 feet long by 8 feet in diameter, has a longitudinal tube, running from near the back end to a point about 4 feet behind the bridge, the flues are in welded barrel-shaped sections, so that thinner plate can be used, and no rivets are exposed to the fire.

Ventilation is produced by a Walker fan, 20 feet in diameter, a Guibal fan being kept in reserve.

The old screening-plant was replaced last summer by improved balanced jigging-screens and coal-cleaning bands of the Wood and Burnett system, so as to enable the increase of output from the new pit to be dealt with. A considerable reduction in labour charges will result from the adoption of mechanical tipplers, and the switchback arrangement on the bank. The plant consists of three sets of jigging-screens, which separate the large coal into sizes, and three large travelling-belts on which the dirt is picked out by boys. The coal is mechanically divided into twelve different sorts, and the plant is capable of dealing with 250 tons of coal per hour.

The coal-washing plant of the Murton type* is capable of dealing with over 800 tons of coal per day. The rough slack is carried direct from the main-screens to the new washery, where it is divided into three classes of nuts and coking-smudge, and washed by means of five trough belts.

* *Trans. Fed. Inst.*, vol. ix., page 42.

The washed smudge for coking is carried partly in waggons and by water a distance of ½ mile, and dropped into large hoppers close to the coke-ovens.

The electric plant consists of an Immisch dynamo and motor, the current being transmitted through a cable to the motor fixed at a distance of 10,000 feet from the dynamo. The dynamo is driven by the fan-engine, the speed being obtained by means of a counter-shaft with pulleys, driving two leather-link belts. The power required to drive the dynamo at full load is 22 horse-power.

Power from the underground motor is transmitted by means of a leather-link belt on to a counter-shaft, which has spur-gearing of 5½ to 1 on to the pump shaft. The three-throw ram-pump delivers 50 gallons of water per minute through 6,000 feet of pipes against a head of 385 feet.

An Ingersoll air-compressor is in operation for working underground hauling-engines.

The brickworks are capable of turning out 20,000 bricks per day. Fawcett's semi-plastic machines have been adopted to use some of the pit shale, and thereby save the high charges for spoil-heap land. A Sercombes (14 chambers) continuous burning kiln, which is an improvement upon the Hoffman type, has been built.

Woodthorpe Pit.—A Capell fan has recently been erected at this pit: it is driven direct by a Willans-and-Robinson engine, running at 280 revolutions per minute.

Four Lancashire boilers of the Arnold type are working at a pressure of 100 lbs. per square inch.

A Robinson coal-washing machine has been in successful operation at this colliery for a number of years.

BIRLEY COLLIERIES.

The workings of the west and south pits are separated by an upthrow fault, to the south, which runs in a continuous straight line eastward. There is a shaft at Birley Moor, used for drawing men, and another shaft at Moorhole, used for the same purpose, and for pumping water.

These shafts are situated near to the outcrop of the silkstone coal-seam, to the west.

The collieries are connected with the Manchester, Sheffield, and Lincolnshire Railway by a single branch line, 3 miles in length, from Woodhouse Junction Station to Birley Vale colliery—passing by the east pit.

West Pit.—The west pit and downcast shaft, 12 feet in diameter, is 426 feet deep to the silkstone coal-seam. The winding-engine has two cylinders each 26 inches in diameter and 4 feet stroke, and is fitted with a parallel drum 14 feet in diameter and an ordinary foot-brake. Single deck cages are used, and two tubs are drawn together.

The whole of the coal is banked and run over a gangway to the screens, where it is tipped on to a series of plain bar-screens of unusual breadth, affording ample facilities for the detection of tubs containing dirty coal. The coal then goes upon several picking-bands, 60 feet long and 4 feet wide, where it is sorted, and the dirt picked out. On leaving the end of the bands, the coal passes over a short bar-screen, so as to remove any small coal made in sorting, and thence into the waggons.

The slack-coal from the screens falls into hoppers, and is conveyed by creepers in troughs to a hopper, whence it is elevated to a revolving-screen, and finally to a shaking-screen. The nut-coal is discharged into a hopper; the fine smudge falls from the revolving-screen into washing-spouts (supplied with water by means of two No. 8 pulsometer-pumps) and thence into a number of large draining-hoppers, from which supplies are drawn for the coke-ovens.

Underground, all the coal is drawn from the dip-working to the pit-bottom, up planes from 7,000 to 9,000 feet long, with an average gradient of 1 in 12.

One plane is worked by a steam hauling-engine, with two cylinders each 16 inches in diameter and $2\frac{3}{4}$ feet stroke; the drum $2\frac{1}{2}$ feet in diameter and 2 feet wide (loose upon the engine-shaft) is driven direct by ordinary clutch-gear. Two other planes, delivering upon one bank-head, are worked by a steam hauling-engine, having two cylinders each 21 inches in diameter and $3\frac{1}{2}$ feet stroke. The engine has two drums (loose upon the shaft) each 3 feet in diameter and 2 feet wide, driven direct by clutch-gear: a separate drum and rope is used for each plane. The trains consist of 30 to 35 tubs, and travel necessarily at a high speed. The ropes are of best plough steel, and $\frac{1}{2}$ inch in diameter.

Water is forced to the surface by two double-acting ram-pumps 9 inches in diameter and 3 feet stroke, driven by a steam-engine with two cylinders 16 inches in diameter and 3 feet stroke, and wheels geared as 3 to 1.

The pit-bottom and plane-tops are lighted by incandescent lamps, by means of a dynamo and engine placed in the pit. Aboveground, arc-lights are used during the winter season.

There are 12 hand-fired boilers of various kinds, and 8 boilers heated by waste-gases from the coke-ovens, working at a pressure of 45 pounds per square inch.

The mine is ventilated by a Waddle fan 40 feet in diameter, driven by a vertical engine, with a cylinder 30 inches in diameter and 3 feet stroke; the air is drawn up two shafts, respectively 9 and 10 feet in diameter.

A second shaft is used for lowering and raising workmen during coal-drawing hours.

South Pit.—The drift from the surface is about 1,800 feet long to the silkstone coal-seam, with a gradient of 1 in 5. The coal is delivered on the same pit-bank and screened with the west pit coal.

A steam-engine, with cylinder 18 inches in diameter and 3 feet stroke, fixed under the landing-stage on the surface, with geared drum, hauls the coal by means of an endless-rope up the drift, and beyond, up an incline for a distance of 6,000 feet. At present coal is drawn to this point by means of a plane-rope and drum, situated at the bottom of the drift, driven from the surface by an endless-rope placed in the Birley Moor pit. Within a few weeks, however, an endless-rope will be worked from the terminus of the present endless-rope, for a further distance of 6,000 feet, 3,600 feet of which length is dipping and the remainder lies over an upthrow fault of 90 feet, beyond which the seam assumes its usual southward dip of 1 in 12.

The rope is placed over the tubs, lashed by $\frac{3}{8}$ inch chains, each about 12 feet long. The loaded tubs move in pairs, the empty tubs in sets of four.

At present the south pit workings are ventilated by means of a Waddle fan 15 feet in diameter.

East Pit.—The eastern or downcast shaft is 16 feet in diameter and 768 feet deep to the silkstone coal-seam. The winding-engine has two cylinders, each 30 inches in diameter and 5 feet stroke, fitted with a parallel drum 15 feet in diameter and a foot-brake. Four tubs are drawn at once in double-decked cages with two tubs on each deck.

The coal is banked at a considerable elevation above the surface and screened under the same roof. The screens are similar to those used at the other pit; the picking-bands, slack-creepers, etc., are of similar type to those previously described.

The pit-bank and screen erections are built of iron columns and girders (the main girders, each about 80 feet long, formed a portion of the ill-fated Tay bridge).

A new shaft has recently been sunk, and the mine is now ventilated by a Waddle fan 45 feet in diameter. Previous to this, the pit was ventilated to the west pit by a Walker fan, 8 feet in diameter, placed underground, and driven by an endless-rope from the main haulage-gear.

The winding-engine has two cylinders 24 inches in diameter and 6 feet stroke, and was used for sinking the new pit. The drum will be parallel, 15 feet in diameter, and the shaft is fitted up with cages for drawing men during working hours. The wooden headgear, about 30 feet high, stands upon brickwork forming part of the raised pit top.

There are upwards of 24,000 feet of empty and loaded sidings for trucks, the whole lying at an inclination of 1 in 60, and after the empty trucks are put into the sidings on the upper side of the pit, they can be lowered by the application of brakes throughout the rest of the system.

The coal is all drawn from dip workings by power applied from the surface, by means of a main endless-rope driven by a steam-engine to the power-shaft at the pit-bottom, whence two endless-ropes are taken to the north and south planes (each about 3,000 feet long). Several other lesser endless-ropes are driven from the same power-shaft. A pump, having two rams, each 7 inches in diameter and 3 feet stroke, driven from the main-rope, forces water to the surface.

There are eight Lancashire boilers, each 30 feet long and 7 feet in diameter.

The pit-bottom and the pit-bank, sidings, etc., are lighted by electric lamps.

About 2,500 safety-lamps are in daily use, all of which are of the Protector type, fitted with two gauzes, and bonneted.

There are 156 beehive coke-ovens at Birley Vale, 84 of which are connected to a large flue, and the waste-gases are used for producing steam under eight boilers.

The briquette-plant is capable of producing about 30 to 40 tons of compressed coal-fuel per day, and is only worked when required.

MESSRS. MARKHAM & CO., LIMITED, BROAD OAKS IRONWORKS.

The visitors were shown examples of work in progress, consisting of winding-engines, hydraulic presses, air-compressors, rock-boring machinery, underground hauling-machinery, etc. Electricity is extensively used as a power for driving the machinery, for lighting, etc., and an electrically-driven travelling-crane was shown at work. Coal-sorting machinery, pit cages, steel headgear, etc., were seen in course of construction.

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 16TH, 1896.

MR. JAMES HASTIE, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY read the report of the Council as follows:—

COUNCIL'S REPORT.

In this the eighteenth annual report, the Council have the pleasure of submitting a favourable statement of the progress of the Institute during the past year.

Although the additions to the membership have been somewhat fewer than usual, there have been, on the other hand, fewer retirals, and the roll at this date contains more members than at the date of the last Annual Meeting. The particulars are as follows:—

On the roll in April, 1895		487
Added during the year		27
		514
Died	2	
Retired	6	
Cut off on account of non-payment of subscriptions	14	
	—	22
On the roll at this date		492

of whom 411 are federated and 81 are non-federated.

Several of the non-federated members were at their own request transferred to the federated list; and there is little doubt that as the value of the *Transactions* of The Federated Institution of Mining Engineers becomes better known by those members who are still non-federated, they will seek participation in the advantage by transference to the federated list.

A recommendation by the Council of The Federated Institution of Mining Engineers to have the members of this Institute classified in conformity with the rules of the Institution was carefully considered by your Council and put before the members for their acceptance. The recommendation was adopted at a special meeting, after due notice had been given. The rules as altered, giving effect to the new classification, came into force on January 1st last. One result of the change is that no new non-federated members are to be elected.

The papers read and published in the *Transactions* during the year are as follows:—

"Electric Coal-cutting at Glenclelland Colliery."
"Pumping-engine Velocity-diagrams."
"Notes on Mining in Portugal."
"The Southern Ayrshire Coal-fields."
"Gold-mining in the Hauraki District, New Zealand."
"The Treatment of Timber for Use in Mines."

The annual excursion in September last was made to some of the new collieries in the Cowdenbeath district of Fife. It was much enjoyed by the members, and in point of numbers was the most successful meeting in the history of the Institute.

Reference was made in the last Council's report to the appointment of a Committee on Mine Drainage. It was found after the Committee had made some preliminary investigations, that the enquiry would involve so much work of a highly technical character and be attended with so great difficulty as to make it undesirable to proceed, at least for the present.

The donations received during the year are as follows:—

Donors.	Donation.
Messrs. E. & F. N. Spon...	Engineer's and Contractor's Illustrated Book of Prices, 1895-96.
Messrs. Hurry & Young...	Aluminium Marsaut Lamp.
Mr. J. M. Ronaldson ...	Inspectors' Reports, 1894.
	Mineral Statistics, 1894, two copies.
	List of Mines, 1894.
	Report for West Scotland, 1894.
Mr. Geo. A. Mitchell ...	£2 for Books for the Library.
Mr. Jas. F. Waldie ...	Mining Journal, 1847 and 1848.

Some additions have been made to the list of exchanges, and valuable information is by this means being placed at the disposal of the members.

There have been ten meetings of Council held during the year.

The adoption of the report was agreed to unanimously.

The Secretary read the following abstract of the Treasurer's accounts for the year:—

The Treasurer in Account with The Mining Institute of Scotland.

For the Session 1895-96.

Receipts.	£	s.	d.
To Balance	127	19	9½
„ Subscriptions, 1 Federated Life Member at £15 15s. ...	15	15	0
„ „ 2 „ Members (1894-95) at 31s. 6d.	3	3	0
„ „ 1 Member (1891-92) at 10s. 6d.	0	10	6
„ „ 170 Federated Members (1895-96) at 31s. 6d.	267	15	0
„ „ 1 „ Member „ at 32s. 6d.	1	12	6
„ „ 230 „ Members „ at 21s. 0d.	241	10	0
„ „ 32 Non-Federated „ „ at 21s. 0d.	33	12	0
„ „ 50 „ „ „ at 10s. 6d.	26	5	0
„ „ 3 Federated „ (1896-97) at 31s. 6d.	4	14	6
„ „ 1 „ „ „ at 9s. 3d.	0	9	3
„ „ 1 Non-Federated „ „ at 21s. 0d.	1	1	0
„ Transactions, etc., sold	4	17	5
„ Bank Interest	0	17	2
„ Rents of Hall	6	4	0
„ Donation	2	0	0
„ The Federated Institution of Mining Engineers ...	5	3	7
	£743	9	8½

Payments.	£	s.	d.	£	s.	d.
By The Federated Institution of Mining Engineers				391	6	5
„ Printing and Stationery				31	15	7
„ Books and Bookbinding				12	18	9
„ Indicators				18	9	7
„ Rents of Halls				16	8	0
„ Gas and Assessments				2	18	6½
„ Stamps, Carriages, Telegrams, etc. ...				11	19	11½
„ Sundry Payments				2	18	5½
„ Cleaning Hall				5	8	0
„ Expenses of Council				20	16	3
„ Salaries				94	12	0
„ Balance in Bank	133	15	10			
„ „ in Treasurer's Hands	0	7	4			
				134	3	2
				£743	9	8½

March 25th, 1896.—Examined, compared with vouchers, and found correct.

J. B. DALZELL,
ROBT. ALISON, } Auditors.

The following gentlemen were elected :—

MEMBERS—

Mr. ARTHUR EDGAR INGRAM, Jarvis' Chambers, Buluwayo, South Africa.
Mr. JAMES RUSSELL, Tannochside Colliery, Uddingston.
Mr. BARCLAY BONTHRONE, P.O. Box 2297, Johannesburg, South Africa

ASSOCIATE MEMBERS—

Mr. JOHN A. WAUCHOPE, Marlow House, Maddox Street, London, S.W.
Mr. P. BENSON, 69, Buchanan Street, Glasgow.

STUDENT—

Mr. DANIEL MARTIN, Clydeside Cottage, Broomhouse.

ELECTION OF OFFICE-BEARERS.

The CHAIRMAN declared the following office-bearers duly elected for the session 1896-97 :—

PRESIDENT.

Mr. GEORGE A. MITCHELL, 63, Bath Street, Glasgow.

VICE-PRESIDENTS.

Mr. JAMES T. FORGIE, Bothwell Collieries, Bothwell.
Mr. JAMES HASTIE, Greenfield Colliery, Hamilton.
Mr. FRED. J. ROWAN, 121, West Regent Street, Glasgow.
Mr. WALLACE THORNEYCROFT, Merryton Colliery, Hamilton.

COUNCILLORS.

Mr. THOMAS ARNOTT, Fernbank, Newton.
Mr. H. M. CADELL, Grange, Bo'ness.
Mr. ALEXANDER FAULDS, Calderbank, Airdrie.
Mr. JAMES GILCHRIST, Lanemark Colliery, New Cumnock.
Mr. ALEXANDER M. GRANT, Gardenhill, Kilmarnock.
Mr. JAMES HAMILTON, 208, St. Vincent Street, Glasgow.
Mr. JAMES HARDIE, Broomknowe, Cambuslang.
Mr. DOUGLAS JACKSON, Coltness Iron Works, Newmains.
Mr. ROBERT MARTIN, Niddrie Collieries, Portobello.
Mr. JOHN MENZIES, Auchinraith Colliery, Blantyre.
Mr. MICHAEL ROSS, Westburn Colliery, Newton.
Mr. JAMES WYPER, Townlands Colliery, Hamilton.

The SECRETARY explained that Mr. Mitchell, the President, was sorry that he could not be present, on account of the death of a near relative. He had asked him to thank the members for the honour which they had conferred upon him in electing him for the third time as their President.

The SECRETARY read an invitation to the members from the executive committee of the Hungarian Mining and Geological Millennial Congress, to be held in Budapest in September next, to attend that Congress.

DISCUSSION ON MR. ROBT. W. DRON'S PAPER ON "THE SOUTHERN AYRSHIRE COAL-FIELDS."*

Mr. J. S. DIXON wrote that, having been long and intimately associated with the Southern Ayrshire coal-field, many years ago he endeavoured to correlate the seams there with those in Lanarkshire. This he did to his own satisfaction, but now finds that it differs from Mr. Dron's correlation and that of Mr. Clarke, of Annbank. It always seemed to him that there was no great difficulty in the matter, as the splint seam in both districts is a sure index, and at Annbank the coal-seams follow quite consecutively at about corresponding distances apart. In this respect, however, the seams in both coal-fields differ considerably, even in comparatively short distances apart.

The splint coal in Ayrshire has a soft coal-seam accompanying it, either quite close or separated by a few inches up to several feet, which exactly corresponds with the splint and virgin coal-seams of Lanarkshire. Then the ell coal-seam of Ayrshire and the Glasgow upper coal-seam are similar in quality and characteristics. His correlation is as follows, viz.:—

Lanarkshire.	South Ayrshire.
Glasgow upper coal-seam...	Ell—Annbank, Drongan, Lugar, etc.
Ell	Main coal—Drongan; Crawfordston—Annbank.
Pyotshaw	Three-dirt coal—Annbank, etc.
Main	Diamond—Annbank; Sillyhole—Dalmellington.
Humph	Jewel—Annbank; Claud—Lugar; Diamond—Dalmellington.
Splint	Splint—Annbank, Drongan, etc.; Chalmerston—Dalmellington; Maid—Lugar.
Virgin	Low Maid—Lugar.

Mr. R. W. DRON wrote with reference to Mr. Martin's remarks† that the coal-seams of the Calciferous Sandstone sometimes attain a workable thickness, but their quality is not good. That is no reason, however, why their presence should be ignored altogether. In reply to Mr. Clarke's remarks,‡ the distance between the Ayr soft or three-dirt coal-seam and the main coal-seam is variable. At some points it is only 30 feet, but 60 feet may be taken as an average. The so-called jewel seam is irregular in its occurrence, it has in one or two instances been found as thick as 2 feet, but it must not be confused with the Bute jewel coal-seam of Cumnock. The Kilwinning coal-seams were

* *Trans. Fed. Inst.*, vol. x., pages 378 and 525.
† *Ibid.*, vol. x., page 526. ‡ *Ibid.*, page 527.

when the timber was fresh. That was the experience which they had all through, and he merely brought it up to enquire whether it had the same effect in the Aitken process. He was pleased to hear that it had not that effect, though he was not sure that the nail test had been satisfactory, because the nails used were different from plate nails, which were tapered. He thought the other tests were very satisfactory, so far as they went, because they proved that the treatment of timber by the Aitken process, so far from lessening its strength, had the effect of keeping it up, the examples referred to showing that after 2½ years it was the same as when it was first used, whereas the untreated timber did not do so by a half. This was very satisfactory, because now in many return air-courses and main roads, especially in air-courses, timber broke under extra strain, and if the strength of this timber could be maintained by salting, he thought it was a very valuable part of the process. He had had two pieces of timber which had been in use for 2 years and 5 months, and had made tests with them. One, which had not been treated, was easily ignited, and the other, which had been treated, became red hot, but when withdrawn from the fire the glow at once left it. The treated specimen also retained its heat longer than the non-treated specimen, which meant that the former was a bad conductor of heat. He thought it was one of the best qualities in the Aitken salting process that it made the timber non-inflammable, because in the majority of the pits in the Hamilton district at least 70 or 80 per cent. of the wood used did not require a long life. After being used two or three days at the face, it was back in the waste, and was practically of no use. The timber in the main roads and return air-courses required special modes of treatment, and he thought that this process was specially adapted for the purpose.

Mr. Henry Aitken (Falkirk) said he did not know that he need add anything at all to what had been said except to explain that he was forced to try and get something to prevent fire. At Niddrie colliery, a fire had occurred about eight or nine years ago. The loss was about £30,000 or £40,000, and how that fire originated nobody knew. It had occurred apparently through the pump-rods, or a wick thrown upon some timber.

In Capeldrae colliery in Fife, a fire originated in a place closely timbered. There was no known cause for it, the place being one where no man was known to have been for many hours before the fire broke out, and there was no coal within 150 feet of it, and where only pump-rods were working. The loss to this company was about £30,000.

As he had said, he had been forced to consider if something could not be done to minimize the danger of fire, and at the same time preserve the wood from rotting. He thought both as regarded its non-resistance to fire and resistance to rot, that the process was as perfect as possible.

He did not know that he need say anything further than that there never was a year without several large fires above and below ground in the collieries of this country, and not only were they disastrous to property but in many cases they were disastrous to life. In some mines abroad, such as De Beers, they had lately read of 500 natives losing their lives through a fire, and at the Anaconda mine on Lake Superior, and the Broken Hill mines in Australia, the monetary loss from the same cause last year was very great.

He thought he might summarize his views by saying that if only treated wood were put into a mine, they might have a fire, and the coal might burn, but the timber would not; and in addition, the treated wood would not rot. How long it would remain fresh he could not say, but it would last at least eight years in return air-courses where untreated wood only lasted two or three years, and it was still perfectly fresh. The cost of treating wood where exhaust steam was used for heating was 1d. per cubic foot for labour and salt.

The CHAIRMAN closed the discussion and moved a vote of thanks to Mr. Martin for his paper, which was heartily awarded.

The SECRETARY read the following paper by Mr. Dugald Baird on "The Duty of Pumping Engines":—

THE DUTY OF PUMPING-ENGINES.

By DUGALD BAIRD.

This paper brings before the members of this Institute a comparatively easy method by which the duty of a pumping-engine may be found, and furnishes a few examples of such.

The question of extracting water from a mine is a most important one, and is becoming more important as mines get deeper and more difficult to drain. It is, therefore, of consequence that we should be well informed as to the best practice in pumping. When it is said that there are, to the writer's certain knowledge, many pumping-engines giving as low as 10,000,000 foot-pounds duty for every hundredweight of Welsh best coal, or coal of equal quality, consumed; whereas it is quite easy to get 80,000,000, and quite possible to get 100,000,000 foot-pounds of duty, no apology is required in introducing the subject of this paper.

While it is not possible to select one type of engine and apply it to all mines irrespective of circumstances, still, if there be a choice of types of engines that have been tested and found to be economical, then that which suits the special circumstances of the case should be chosen. For example, if a pit be 1,200 feet deep, and has a growth of water of 50 gallons per minute, the most likely type of pumping-engine to be employed is one driven by electricity; whereas in a pit 600 feet deep, with a growth of 1,000 gallons of water per minute, no one would think of applying electricity.

It is well not only to know a great deal about all economical types of pumping-engines, so as to be able to choose the proper one for any particular set of circumstances, but also to be well-informed about all the bad types, so that they may be avoided.

It is lamentable for both landlord and tenant to find that perhaps 10 to 15 per cent. of the gross output of a colliery is consumed in pumping water, whereas if a proper engine were doing the pumping only 3 per cent. would be required. In addition, with a bad type of engine requiring a large fuel consumption, the capital spent for extra boilers is large,

and would go far in purchasing a good engine, and, in addition to extra boilers, extra labour is to be paid for to fire them, all of which is a steady drag on the colliery, which should be avoided.

The question submitted for consideration is: how are we to find out whether a pumping-engine is a good one or not?

A method recommended by consulting engineers begins in the stoke-hole and ends with the actual work done. The scope of this method will be better understood by perusing the list of questions that require to be answered and the list of observations that require to be recorded:—

(A) Analysis of the coal used during the test.

(B) Carbon-value of the coal used, so that the exact amount of heat (if complete combustion be got) that is placed under the boilers is known.

(C) Analysis of the flue-gases, and the temperature of the same as they pass to the chimney, so as to ascertain whether complete combustion has been attained or if too much air has been admitted; also how much heat is being sent up the chimney.

(D) Weight of coals used and weight of ashes removed, so as to find what is over and above the natural ash in the coal, and thus ascertain how much unburnt coal is being wasted.

(E) The temperature of the feed-water going to the economizer, and its temperature as it enters the boiler, also the quantity of water used.

(F) The condition of the boiler as regards soot outside and scale inside; the area of boiler exposed to the fire and the area of the gratings, so that the boiler efficiency may be calculated.

(G) The percentage of water in the steam supplied to the engine caused by priming, radiation, condensation, and badly arranged steam-pipes.

(H) The indicating of the engine, which includes the following observations and calculations:—

(1) Size and speed of engine.
(2) Pressure of steam in the pipes at the engine.
(3) „ „ in the boilers.
(4) Initial pressure of steam in the high-pressure cylinder.
(5) Terminal pressure of steam in the low-pressure cylinder.
(6) Average pressure of steam in all the cylinders.
(7) Vacuum in the condenser, and atmospheric pressure.
(8) Total indicated horse-power.
(9) Point of cut-off in the high-pressure cylinder.
(10) Ratio of expansion.

(11) Weight of feed-water used per hour per indicated horse-power.
(12) „ coal burned „ „ „
(13) „ steam used „ „ „
(14) „ „ as calculated from the indicator diagrams.
(15) Quantity of water collected at the steam-traps, relief-cocks, and steam-jacket cocks.
(16) Total quantity of heat supplied to the engine per minute.
(17) „ „ discharged into the condensers per minute.
(18) Percentage of heat transformed into useful work.

(I) Efficiency of shaft-pumps, including:—
(1) Size of rams and buckets.
(2) Length of stroke.
(3) Number of strokes per minute.
(4) Theoretical discharge of each pump.
(5) Actual discharge of each pump.
(6) Vertical height of each lift.
(7) Percentage of useful work done.
(8) Size of suction and discharge-pipes, and other details which vary at different places.

Now, while it may be admitted that all this information is useful, valuable, and most of it indispensable—if the whole question is to be gone into of (*a*) the value of the coal; (*b*) the efficiency of the boiler; (*c*) the efficiency of the economizer; (*d*) the efficiency of the steam-pipes; (*e*) the efficiency of the engine; and (*f*) the efficiency of the pumps—yet it is possible to find out what are the best types of pumping-engines as applied to mines by a simpler process. For this purpose, it is the efficiency of the engine that is alone required. In that case, only a small proportion of the information detailed from A to I would be required.

This brings us to the method carried out by the writer, which he has found to be of great service. It may appear to some members to be somewhat empirical and unscientific, still the writer is of opinion that unless some such method can be adopted and found sufficient (and he claims for this method that it is so) it will be, if not altogether impossible, extremely impracticable to investigate the efficiency of many installations.

At almost every colliery the pumping-engine is attached to the same range of boilers as the other engines, some of which it would be found

could not be detached for testing purposes, and others which it would not be desirable even to stop for a short time, notably the fan-engine where fire-damp is prevalent.

In addition, the difficulties of testing the useful work done by the pumps in almost every case would be such that they could not be overcome. Imagine, for instance, a Cornish engine with six bucket or plunger-sets, each delivering into the one above, and some getting water at their own particular lodgments, and some running back water to keep them going solid. The actual quantity of water delivered per minute or per stroke would require to be taken, which is, practically speaking, impossible.

The following is a description of the method that the writer has adopted, and a test of duties taken on the basis of that method :—

(A) The water in the boilers being lowered to the lowest safe working place so as to prevent priming, its level is carefully marked so that it may be the same at the beginning and end of the test.

(B) By means of two boxes of known capacity, the amount of water actually put into the boilers during the test is carefully measured. The temperature of the water in the boxes is also required in order to get the exact weight per gallon, and it is necessary that the boilers be fed by means of an injector, so that the steam taken from the boilers for this purpose is returned along with the feed-water. The injector should not be allowed to overflow, but if it does overflow, the overflow is to be collected and returned to the boxes. It is necessary that the blow-off pipes of the boilers should be exposed, so that if there be any leakage from them, it may be caught and returned to the boilers or accounted for.

(C) No attention need be paid to the state of the fires at the beginning of the test, during the test, or at the end of it, or to the amount of fuel used, or to the quality of the fuel, or to the good or bad stoking, or to scale on the plates of the boiler. The steam-joints or fittings should be in good repair before starting, and if the donkey feed-pump be used to fill the test-boxes, its exhaust steam must be led into a barrel of water and condensed, the amount of steam used being thereby ascertained.

(D) All the other engines, including the pumping-engine, should be stopped if possible, but if not possible, as in the case of the fan-engine, a register should be kept of the total number of strokes made during a first test, so that during the next test the fan-engine may be run at the same speed. This first test is what may be called the dead loss test. The steam in the boilers will be maintained at the regular working pressure, but must not be allowed to blow-off at the safety-valves. The duration of this test will depend on how long the pumping-engine can be allowed

to stand—12 hours would be a very good length of test, but no test to be at all accurate should be of less than 4 hours' duration. All tests should be done twice, and if they do not agree to within 5 per cent. should be repeated until they do agree. The amount of water that has been put into the boilers during the test is of course carefully noted. The majority of these tests will, as a matter of convenience, be done on idle days.

(E) Another test on exactly similar lines, and called the working test, is made, but in this the pumping-engine is working, whereas it was standing in the previous one. This test should also be verified by repetition. The amount of water used during the dead loss test will be deducted from the amount used during the working test, and the net amount will be debited to the pumping-engine's account.

(F) The pumping-engine during the working test would be indicated not less than three times, not because it is necessary to indicate it to arrive at the true efficiency of the engine, but to ascertain whether there is not something radically wrong with the internal arrangements and the distribution of steam, and as a useful adjunct to the test.

(G) As regards the pumps themselves, the ascertainment of the actual amount of water pumped at each stage is a very difficult matter, and, in the writer's opinion, any attempt to find this out would be futile. The amount delivered at the surface could, in some cases, be got, but very often a quantity of water is taken away to the condenser, so that, all things considered, there seems no alternative but to take the theoretical amount that the pump would discharge. By so doing, all engines would be placed on the same basis, and this would also be the case should, say, 5 per cent. be deducted from all. The writer prefers to take the theoretical discharge as a basis, being of opinion that in almost every case it takes as much steam to pump a smaller quantity of water as it does to pump the full quantity, whether the smaller quantity be due to leaking valves, packings, or joints, or slip at the valve. In most cases the engine lifts the pumping-rods, and they, being heavier than the water, force it up the pipes during the downstroke of the engine. In these cases it, of course, takes the same amount of steam to lift the rods every time, independently of how much or how little water is being pumped. Even in the case of an underground steam pump, forcing water to the surface in one lift, it takes as much steam to force half of the theoretical quantity as it does to force the full quantity, for although one half of the water is finding an escape through the suction-valve or at the packing-gland, the pressure at the end of the ram or bucket, so long as any water is being delivered at the surface, is just the same as it would be if everything were

in order; and on indication of the steam-cylinder it would be found that the terminal pressure in the high-pressure cylinder would be the same in both cases. The terminal pressure is the real guide to the amount of steam used. One precaution is, however, necessary—all the pumps must be kept going on solid water, as in almost all cases it takes less steam to pump a mixture of air and water than solid water, the exception being when an engine on the surface working with rods in a vertical shaft has no bucket-lifts, which is very seldom the case; but in that event, the rods being heavier than the water, the steam is used in lifting the rods, and not in lifting the water. It may here be noted that water run back from the rising-main of pipes to keep the pumps solid does not interfere with the amount of steam used. It is to be recommended, however, before the test is begun, that all defective valves, buckets, and packings be renewed, so that the pumps could be said to be in good working order. It is also obvious, if the piston-ring of the steam-cylinder be broken or worn, or the steam-valves in a bad state of repair, that such defects must cause the engine to give bad results, and all such gross defects must, if the type of engine has to get a fair chance, be put in order. Of course, should the test be carried out, the result will be the duty as it is under these circumstances.

(H) Having, by means of the test described, found out how much water has been put into the boilers, and having by calculation found out how much work has been done, it remains to reduce them to some standard so that the result may be stated. The standard usually adopted for pumping-engines is foot-pounds of work done per cwt. of coal used, and this has been taken in the following tables. But should anyone who has been accustomed to reduce results to pounds of coal used per hour per indicated horse-power desire to use that standard, it is easy to find the one from the other. By calculation it is found that 1 lb. of coal used per hour per indicated horse-power on the one standard is equal to 221,760,000 foot-pounds, or taken approximately, and in a way easily remembered, 222,000,000 foot-pounds of duty.

(I) Now, some coals give an evaporative efficiency of 14 lbs. of water per lb. of coal consumed, while other coals only give 5 lbs. of water per lb. of coal. The writer has adopted as a basis a coal giving 10 lbs. of evaporative efficiency, so that if 1,120 lbs. of water be evaporated it signifies that 1 cwt. of coal has been burned. The duty is thus expressed in millions of foot-pounds per cwt. of coal on a 10 lbs. evaporative basis.

Table I. contains examples of tests made under the foregoing conditions. These tests were made rather hurriedly; most of them have been verified, while others have not. They are not to be taken as

TABLE I.

Name of Colliery	Leven.	Leven.	Leven.	Durie.	Wellsgreen.
Reference Number	1.	2.	3.	4.	5.
Date of test	Nov., 1895	Dec., 1895	Dec., 1895	Jan., 1896	Jan., 1896
Type of pumping-engine	Bull	Davey differential	Duplex	Davey differential compound	Compound Bull
Position of pumping-engine	Surface	Under-ground	Under-ground	Surface	Surface
Dimensions of cylinders—					
Diameter; inches	100	36	22	33, 52	28, 48
Stroke; inches	144	48	24	108, 144	144
Age of engine; years	18	2	2	8	6
Condition of engine	Good	Good	Good	Good	Good
Duration of test; hours	4½	4	4	4 1/15	6
Pressure of steam at boiler during test; lbs. per square inch	53	53	53	80	77
Water used per hour during dead loss test; gallons	751	751		497	122
Water used per hour during working test; gallons	1,530	1,925		1,032	416
Nett water used per hour during working test; gallons	779	1,174		535	294
Temperature of feed-water in test-boxes; Fahr. degrees	44	42		40	58
Temperature of water going into boilers; Fahr. degrees	130	125		118	140
Dimensions of pumps	Plunger sets— 3 of 24 ins. 2 of 16 ,, Bucket sets— 1 of 16⅝ ins. 1 of 16½ ,, 1 of 14½ ,,	Quadruple plunger sets— 11 inches	Quadruple plunger sets— 12 inches	Plunger set— 2 of 24 ins. Bucket set— 1 of 16 ins.	Plunger set— 1 of 18 ins. Bucket set— 1 of 18 ins.
Length of possible stroke; ins.	144	48	24	144	144
Length of actual stroke; ins.	141	46	23	141	138
Number of strokes per hour	133	968	705	263	141
Theoretical quantity of water pumped per minute to the surface; gallons	753	900	0	1,030	311
Theoretical amount of work done per stroke; foot-pounds	2,962,080	65,912	405,000	1,265,261	667,000
Total depth of pit; feet	900	900		600	504
Total duty per 1,120 pounds of water put into boilers; foot-pounds	50,265,312	41,360,000		69,705,890	35,827,200

recording the ultimate values of the relative engines, and were made principally to illustrate the mode of testing, as above described.

After these results have been tabulated, it will sometimes be found that different types of engines give almost the same duty. In that case, another test may have to be applied, so as to ascertain their relative merits as regards steady action. As pointed out in a short paper by

the writer recently read to the members, entitled "Pumping-engine Velocity-diagrams,"* the pumping-engine that can perform a certain amount of work at a speed nearest to that of the uniform velocity, and at the same time give a sufficient pause at the ends of the stroke, is superior to one that, although giving out the same duty, does its work by leaps and bounds. This test is a very simple one when one has a machine for the purpose. The writer is pleased to be able to say, that as suggested in the paper referred to, the Council of the Mining Institute of Scotland have had a velocity indicator made, and the diagrams shown in Figs. 1 to 7 (Plate IX.) have been taken by it, the results being recorded in Table II.

TABLE II.

Reference Number.	Type of Pumping-engine.	Speed in Double Strokes per Minute.	Length of Stroke.	Average Velocity per Minute.	Average Velocity of Up-stroke per Minute.	Average Velocity of Down-stroke per Minute.	Greatest Velocity of Up-stroke per Minute.	Greatest Velocity of Down-stroke per Minute.	If Average Velocity be taken at 100 Feet per Minute, then Greatest Velocity per Minute is equal to.
			Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1	Bull	2·6	12	62·4	124·0	99·0	166·5	123·5	266
1A	Do.	3·0	12	72·0	135·0	99·0	187·0	120·0	260
2	Underground Davey differential ...	10·0	4	80·0	106·4	78·6	132·3	144·7	180
2A	Do. do. ...	19·0	4	152·0	182·0	170·3	251·8	270·0	177
3	Underground duplex	16·5	2	66·0	120·0	122·0	140·0	140·0	212
4	Surface differential ...	5·0	12	120·0	180·0	144·0	214·0	210·0	178
5	Compound bull ...	2·3	12	55·4	96·0	68·5	142·5	76·0	257

Figs. 1 and 2 (Plate IX.) are the speed diagrams of the bull pumping-engine; Fig. 3 and 4 of the underground Davey differential pumping-engine, No. 1 pit; and Fig. 5 of the underground duplex pumping-engine, No. 2 pit, Leven collieries; Fig. 6 of the Davey differential compound pumping-engine at Durie colliery; and Fig. 7 of the compound bull pumping-engine at Wellsgreen colliery.

The speed diagrams (Figs. 1 to 7) are not given as ultimate diagrams for the types of engines tested, but to illustrate what is required. They were taken with the pumping-engines going at their usual speeds, but for proper comparison so as to put every pumping-engine on the same basis, a set of diagrams should be taken when the pump-rods are moving at an average speed of 100 feet per minute. For a little consideration will show

* *Trans. Fed. Inst.*, vol. ix., page 138.

that an engine making a small average velocity, by going fast and making long pauses at the ends of the strokes will, on the comparison of maximum with average velocity, come out badly.

A series of steam-cylinder indicator-diagrams were taken from all the pumping-engines, referred to in Table I., with the McKinnell and Buchanan improved indicator. The leading feature of this indicator is that the springs are arranged externally, and are thus removed from direct contact with the steam-piston of the indicator. A more accurate register of the steam-pressure is obtained, it being a recognized fact that a spring has not the same rigidity when it is hot as when it is cold. In the usual arrangement, the spring is subjected to variations of temperature, so that this indicator is an improvement in that respect; besides, the changing of the springs to suit the different pressures to be registered is more easily carried out.

Should this paper succeed in drawing the attention of the members to the subject of the duty of pumping-engines, and bring forth such a criticism as the subject deserves, or should it be the means of enabling any of the members to test their pumping-engines in a way not usually adopted, then this paper will not have been written in vain.

To illustrate Mr Dugald Baird's Paper on "The Duty of Pumping-Engines."

No. 1.—BULL PUMPING-ENGINE,
LEVE COLLIERY.

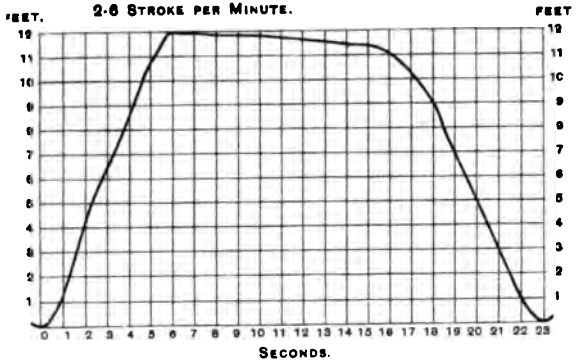


FIG. 1.

No. 4.—DAVEY DIFFERENTIAL COMPOUND PUMPING-ENGINE,
DURIE COLLIERY.

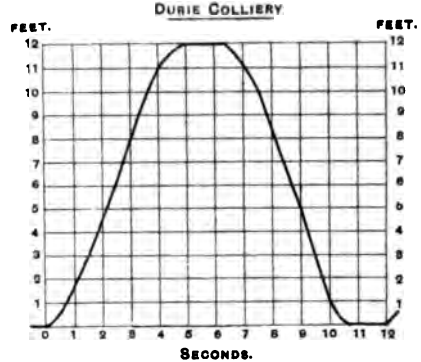


FIG. 6.

No. 5.—COMPOUND BULL PUMPING-ENGINE,
WELLSGREEN COLLIERY.

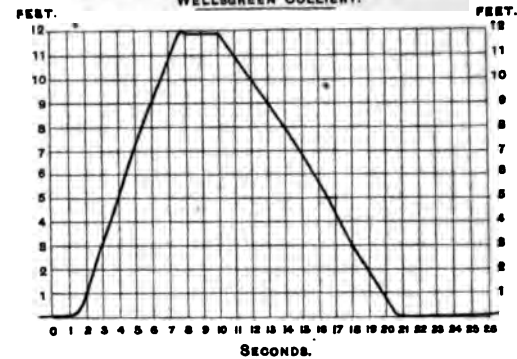


FIG. 7.

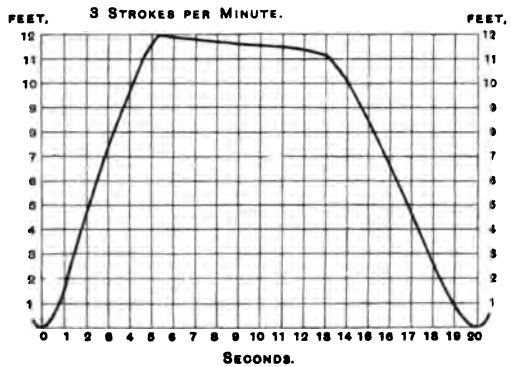


FIG. 2.

No. 3.—UNDERGROUND DUPLEX
PUMPING ENGINE, No. 2 PIT.
LEVEN COLLIERY.

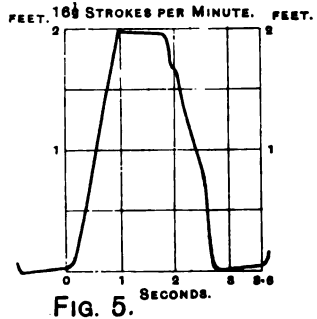


FIG. 5.

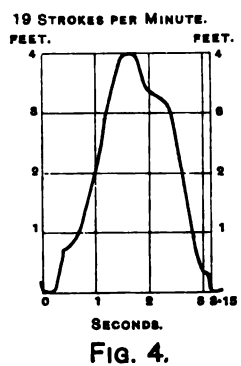


FIG. 4.

No. 2.—UNDERGROUND DAVEY DIFFERENTIAL
PUMPING-ENGINE, No. 1 PIT,
LEVEN COLLIERY.

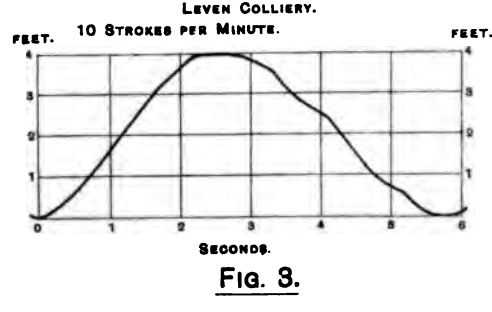


FIG. 3.

ung Institute of Scotland.
Transactions 1895-6.

And.w Reid & Comp.y Ltd. Newcastle on Tyne

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, MARCH 16TH, 1896.

MR. E. B. WAIN, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were confirmed.

The following gentlemen were elected :—

MEMBER –

Mr. THOMAS HENRY ARMSTRONG, Mechanical Engineer, Blanchland House, Willington Quay-upon-Tyne.

ASSOCIATE MEMBER—

Mr. LEVISON WEDGWOOD, Boiler Maker, North Road, Cobridge.

ASSOCIATE—

Mr. WALTER ROEBUCK, Under-manager, Talk-o'-th'-Hill.

Mr. E. B. WAIN read the following paper on "The Use of Petroleum in Safety-lamps":—

THE USE OF PETROLEUM IN SAFETY-LAMPS.

By E. B. WAIN.

Although the use of petroleum underground in open lamps has with good cause been universally condemned, there appears to be no reason why this class of illuminant should not be more largely used with a suitable burner in a locked safety-lamp. The light given is better, and the cost of oil consumed is reduced very considerably. Both of these are important considerations, and as increased efficiency is combined with economy, there seems to be a probability that the use of petroleum for this purpose will be considerably extended in the future.

Since the issue of *Report of the Accidents in Mines Commission* in 1886, it has become the custom to use a mixture of colza oil and petroleum in varying proportions, and no doubt many of the so-called safety-lamp oils (the preparation of which is supposed to be a trade secret) are composed of such a mixture.

In practice, the author finds that a mixture of 4 parts of pure colza oil to 3 parts of Russian petroleum, having a flashing-point of about 100 degs. Fahr., makes the most suitable mixture for use in Marsaut and Mueseler lamps with a flat wick $\frac{5}{16}$ inch wide.

It is important that the petroleum used should be of good quality, and that the flashing-point should not be lower than 100 degs. Fahr. (open test). The mixture of the two oils appears to be of a mechanical nature, and the flashing-point of the mixed oil is very little higher than that of the petroleum used. An oil mixed in the proportion mentioned above, using petroleum with a flashing-point of 102 degs. Fahr., shows the flashing-point of the mixture to be about 110 degs. Fahr.

The Commissioners recommended that the petroleum used should not have a lower flashing-point than 80 degs. Fahr., and if care be taken that the oil is of the proper quality, there should be no danger whatever in the use of petroleum in a mixed oil.

If, however, it be safe (and an experience of several years has shown that it is perfectly safe) to use a mixture of colza and petroleum in safety-lamps (and, as has been noted above, the mixture has practically the same

flashing-point as the petroleum used in mixing), there seems to be no reason whatever why petroleum should not be used exclusively if the safety-lamps and lamp-burners be suitable for the illuminant.

The Commissioners experimented with "petroleum or paraffin oils of such flashing-points as might warrant their use, under ordinary circumstances in miners' lamps," but they found a "smoky, flaring flame," and the results were not considered satisfactory.

There are at the present time several patterns of burners, suitable for use with petroleum in safety-lamps which, overcome the difficulty just mentioned. They can be applied to almost any type of safety-lamp at a trifling cost. There seems to be no reason why advantage should not be taken of such benefits of superior illuminating-power and reduced cost as will be gained from their use.

The author now proposes to submit the description and particulars of tests of the several patterns of burners. In making these tests six burners have been used.

(1) Ordinary flat wick oil-burner, using wick ½ inch wide (Fig. 1).
(2) The Heath & Frost burner (Fig. 2).
(3) J. C. M. (Johnson, Clapham, & Morris burner, Fig. 3).
(4) The Ashworth burner (Fig. 4).
(5) The Thorneburry (Barton) burner (Fig. 5).
(6) The Kaye burner (Fig. 6).

Although the various burners have been designed by different persons there is a very remarkable family likeness between them, the difference in three cases practically consisting of a variation in the shape of the wick-tube.

(1) The ordinary flat wick-tube is mentioned, not as an instance of a burner which the author would recommend for the purpose of burning petroleum, although it appears under most circumstances to answer all requirements. In fact, as regards its illuminating-power it is found to be equal, and in some cases superior, to some of the burners specially designed for the purpose. The drawback is that the pricker-slot in the wick-tube is exposed, and when the lamp is heated by artificial means to about 150 degs. Fahr. the flame increases considerably in height. The oil-consumption is also greater in proportion to the illuminating-power than in most of the other burners.

(2) In the Heath & Frost burner, the pricker-tube is covered with a special brass cap, so as to render the escape of vapour from the heated oil practically impossible. As a further but apparently unnecessary precaution, the glass ring in the body of the lamp is extended up to

the protecting cap, so as to form a further cover and separation between the flame and the oil-vessel. This precaution appears to be unnecessary, because the same burner when fitted to a lamp without the protecting ring burns efficiently, and in every way appears to be quite as satisfactory.

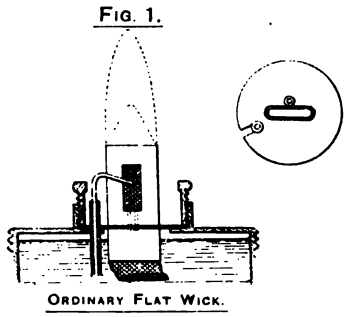


FIG. 1.

ORDINARY FLAT WICK.

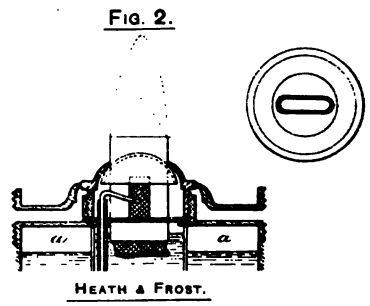


FIG. 2.

HEATH & FROST.

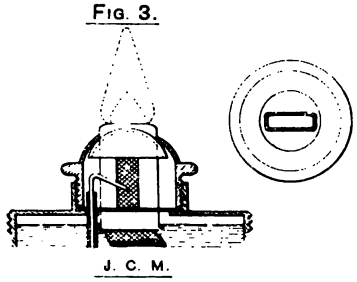


FIG. 3.

J. C. M.

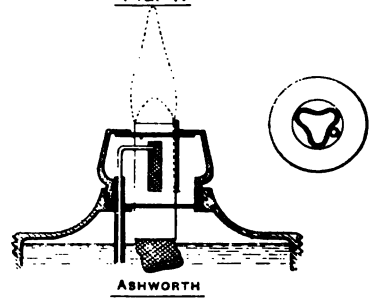


FIG. 4.

ASHWORTH

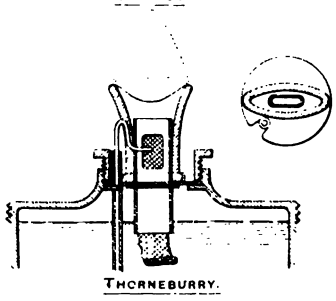


FIG. 5.

THORNEBURRY.

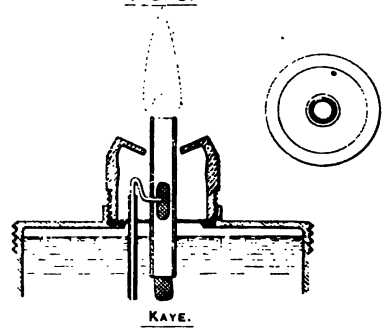


FIG 6.

KAYE.

In the safety-lamp for which this burner was specially designed there is an air-chamber *a* (Fig. 2), to allow of the expansion of the oil when heated, and to prevent the lamp from being overcharged with oil. This adds somewhat to the length of the oil-vessel, but it is a useful addition, although only necessary as a precaution against careless filling.

This burner, as will be seen from the table of experiments, is with one exception the most economical as regards oil-consumption, although the illuminating-power is a trifle lower than in some of the others. A flat wick, ½ inch wide, is used with the burner.

(3) The J. C. M. burner is very similar to the last described, the chief difference being the omission of the second protecting ring. In this burner the wick-tube is kept lower, almost level with the protecting cone, and the corners are removed to allow of lateral expansion of the flame. The consumption of oil is greater than with the Heath & Frost burner, and the illuminating-power is the same as in that pattern.

(4) The Ashworth burner differs from the last two, chiefly in the shape of the wick-tube. The protecting cap is the same in principle, but with a flat instead of domed top. The wick-tube, which contains a wick of the same size as the last-mentioned burner, is of a peculiar triangular shape, which appears to promote more perfect combustion. This burner gives, with a Marsaut lamp, a better illumination at the same time as a lower consumption of oil.

This statement only, however, applies to the burner when used in a Marsaut lamp, as the chimney-draught of the Mueseler lamp does not appear to be so suitable for this shape of flame, and although the illuminating-power is equal even in such a case to that of the flat wick in the other types, the consumption of oil is greater.

(5) The Thorneburry (Barton) burner differs in principle from the three previously mentioned. It is constructed so as to burn the oil, after it has been previously heated, to a vapour by means of a special porcelain tube. The result is a pure flame equal to the best results obtained with the Ashworth burner, although with a larger oil-consumption. Owing to the special construction of this burner, the flame is more difficult to extinguish than in the other type, and as the light flickers more when the lamp is moved, the burner is not therefore quite so suitable for travelling.

When this burner is used with the Thorneburry lamp the benefits of the superior combustion derived from the construction of that lamp (which was specially designed for the use of petroleum, and which has been described by the author in a previous communication to this Institute*) is very evident, and although the consumption of oil is high, the perfect combustion of the oil is shown by the high illuminating-power. In this burner the wick used is only ¼ inch wide.

(6) The Kaye burner is somewhat similar to the Heath & Frost, J. C. M., and Ashworth. The round wick, ¼ inch in diameter, gives a lower illu-

* *Trans. Fed. Inst.*, vol. iii., page 226.

minating-power, although superior to that of the ordinary colza-oil lamp. The consumption of oil is the same as with the Heath & Frost burner, but yields 20 per cent. less light. It requires some attention, as the flame draws rapidly up the chimney when the lamp is heated. The author has found that this burner is much improved and the tendency to elongation of the flame much reduced, if the top of the round tube be slightly belled out. With a flat wick, there is no doubt that this burner could be considerably improved, and would be equal to the average intensity of the others described.

The following table shows comparative tests of the various burners, with particulars of oil-consumption and illuminating-power, as compared with an ordinary double-gauze Marsaut lamp, burning a mixture of 4 parts of pure colza and 3 parts of Russian petroleum (102 degs. Fahr. flashing-point and specific gravity 0·825).

TABLE OF THE RESULTS OF THE EXPERIMENTS, ETC.

No. of Test.	Name of Lamp.	Name of Burner.	Oil Used.	Time of Burning of a Charge of 2 Ounces.	Wick.	Comparative Illumination.	Cost per 10 Hours.
				Hours.			d.
1	Mueseler ...	Kaye ...	Petroleum	11	¼ in. round	1·20	0·076
2	Ashworth-Mueseler	Ashworth ...	,,	9½	⅜ in. flat in oil tube	1·53	0·082
3	Mueseler ...	Heath & Frost	,,	11	½ in. flat	1·45	0·076
4	Marsaut ...	,, ,,	,,	11	,,	1·48	0·076
5	,,	Plain ...	,,	9¼	,,	1·53	0·090
6	,,	J. C. M. ...	,,	9¼	,,	1·48	0·090
7	,,	Ashworth ...	,,	12	½ in. flat tube	1·71	0·070
8	,,	Barton ...	,,	10	¼ in. flat	1·71	0·084
9	Thorneburry (short type)	,, ...	,,	8½	,,	2·20	0·099
10	Marsaut ...	Plain ...	Mixed oil	11¼	$\frac{5}{16}$ in. flat	1·00	0·190
11	Mueseler (Belgian)	,, ...	,,	13	,,	0·93	0·150

The lamps burning petroleum only were charged with a locally distilled oil (130 degs. Fahr. flashing-point, and specific gravity of 0·795), which appears to be very suitable for the purpose

In the tests for oil-consumption, the flame was raised as high as could be carried without smoking, and, except in the case of the Kaye burner, in which the flame occasionally required regulating, the lamps which were burning petroleum were left untouched, and did not require snuffing until the whole of the oil was exhausted. The flame of the oil-lamp had to be trimmed with the pricker about once in every two hours.

In the photometric tests, the lamps were compared (after being lighted for 2 hours) with a Marsaut safety-lamp, the light from which

was taken as a standard, and the figures given in the sixth column of the table are the illuminating-power as compared with that standard, which may be taken as approximately 0·50 of a standard candle.

The cost is based on the current prices of the illuminant used.

It will be seen from the table of experiments that safety-lamps with petroleum burners are all superior in illuminating-power to those with ordinary colza-oil burners, and that the quantity of petroleum burned is approximately in proportion to the illuminating-power of the lamp.

The Thorneburry safety-lamp, fitted with the Thorneburry (Barton) burner, gives the best light, but in changing from oil to petroleum the peculiar construction of this lamp renders it necessary that the old lamps should be discarded, and it is probable that burners which can be fitted to lamps of the ordinary type will be more popular.

It may be thought that savings which require to be calculated to 0·001d. are of small importance; but when it is noted that the saving, as compared with the Marsaut safety-lamp burning mixed oil at a cost of 0·190d. per day, and the same lamp, with almost twice the light, fitted with the most economical of the petroleum burners, at 0·070d. per day, is equal to a saving of £125 per year at a colliery using 1,000 lamps for, say, 250 days per year, it will be seen that the matter is one which is worth consideration from an economical point of view.

The author sees no substantial objection to the use of such burners, and hopes, during the discussion on his paper, to hear that the experience of other members will confirm the favourable opinion which he has formed on the use of petroleum in safety-lamps.

Mr. JOHN HEATH said that one burner referred to by Mr. Wain was just like the Heath & Frost, only the glass ring had been left out. Another burner had a round wick, and was not tight, so that the oil could get out. He had tried a Thorneburry burner and could not get as good a light from it as from the Heath & Frost.

Mr. LOCKETT asked whether the President had had any experience in testing for gas with the oil which he proposed as compared with the heavier oils?

The PRESIDENT said, that he had simply taken the burners as he found them in use. There was a strong family likeness between three of the burners, as he stated in his paper. Mr. Heath had spoken about the

Thorneburry burner not giving sufficient light, and about the smallness of the light when travelling. There was no doubt that the heated tube with the vapour burning at a distance from the wick converted the oil into gas; the flame was more sensitive to movement than a flame supported by a more perfect oil-supply at the point of ignition. There seemed to be no difficulty in fitting five of the special burners to any safety-lamp. In reply to Mr. Lockett, he (Mr. Wain) said that it was a comfort to use a lamp with the petroleum in it when testing for gas, because he was able to draw the flame to the smallest possible blue flame. He was able to detect a smaller proportion of gas than with an ordinary safety-lamp.

Mr. Wm. Heath observed that the greatest possible credit was due to the President for the pains at which he had been with respect to the oil with which he had experimented. He moved a vote of thanks to the President for his paper.

The motion was agreed to.

The following paper was read by Mr. Cowlishaw on "The Woodworth Progressive Cut-off Gear for Winding-engines:—

THE WOODWORTH PROGRESSIVE CUT-OFF GEAR FOR WINDING-ENGINES.

By W. G. COWLISHAW.

As a supplement to the paper * on the above subject, prepared by Mr. B. Woodworth and the writer, he has taken two indicator-diagrams and has computed the steam consumption, so as to show more clearly the advantages of such a device.

The indicator-diagrams (Figs. 1 and 2), are each for a complete wind, taken under similar conditions of load, etc., and, in fact, are consecutive diagrams. A complete wind consists of 29 revolutions of the engine, and it will be seen that steam is only admitted for 21 revolutions, the remaining 8 revolutions being run by momentum. The actual point of the cut-off by the valves is marked by round dots on the diagrams.

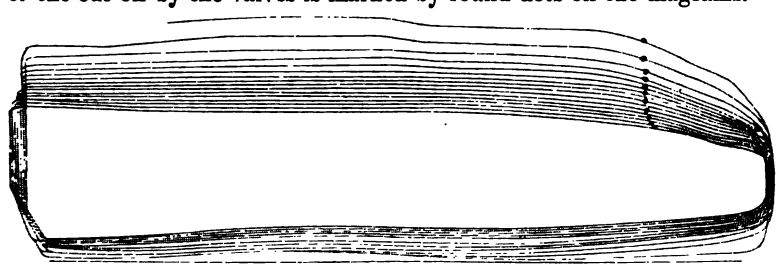


Fig. 1.

The first indicator-diagram (Fig. 1) was taken with the winding-engine working under ordinary conditions, and it will be seen that steam is cut-off in each revolution at about 0·85 of the stroke, allowing but 0·15 of the stroke for expansion.

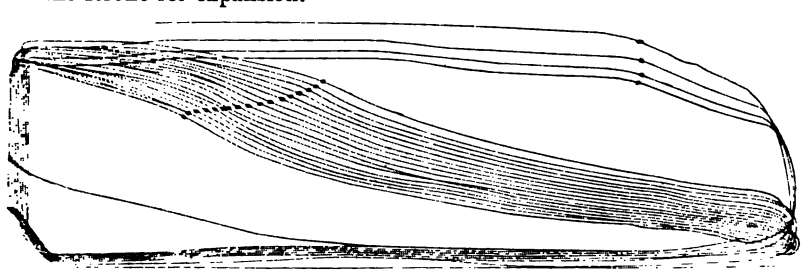


Fig. 2.

The second indicator-diagram (Fig. 2) was taken with the Woodworth gear in operation: it shows that for the first four revolutions steam was

* *Trans. Fed. Inst.*, vol. x., page 470.

admitted for about 0·85 of the stroke, the gear then coming automatically into operation, commencing at the fifth revolution with a cut-off of about 0·40 of the stroke, and at the 21st revolution cutting-off at about 0·20 of the stroke. The progressive action of the gear is very clearly shown by the position of the dots in the diagram (Fig. 2).

The actual amounts of steam used for a complete wind are as under:—Where the gear is not in operation, as shown by the indicator-diagram (Fig. 1), 2,376 cubic feet. Where the gear is in operation, as recorded in the indicator-diagram (Fig. 2), 1,435 cubic feet, showing a saving of, as measured on the diagrams, 40 per cent., or 941 cubic feet.

The actual economy as measured in the firehole was the saving of the labour of one fireman out of three, and in addition to the saving of labour there is the more important saving of the fuel that this workman would throw upon the boiler-fires.

It will be noticed that the back pressure on the first indicator-diagram (Fig. 1) is considerable, whereas in the second diagram (Fig. 2) owing to reduced terminal pressure, it is much less, showing that either the ports or exhaust-pipes in this case are somewhat cramped.

The writer finds that the period of winding, for a complete run, including banking, is about 1 min. 13 sec. This result for an engine winding from a depth of 1,863 feet, with three-decked cages, each landed separately with two tubs on a deck, is no doubt good work. The actual running time averages about 54 seconds, the piston speed for seven or eight seconds during the fastest period of the run being as high as 720 feet per minute, while the cages are travelling at the same time at the rate of about 43 miles an hour.

The writer has made careful enquiries and finds that the application of the Woodworth gear has not increased the time of winding. Recently the Woodworth gear was undergoing slight alterations, and in consequence of this the day's output of coal was approximatively 100 tons less than usual, owing to the impossibility of keeping either steam or water in the boilers. In the writer's opinion no stronger testimony as to the merits of the Woodworth gear could possibly be adduced.

The PRESIDENT said there was no doubt that the gear introduced by Messrs. Woodworth and Cowlishaw at the Sneyd colliery was one of the most important improvements applied to winding-engines for many years past. Recently, he had referred to a paper read just twenty years ago by

Mr. John Daglish, before the North of England Institute of Mining and Mechanical Engineers,* on the same subject. Expansive working of winding-engines was recommended by Mr. Daglish, but there seemed to have been very little progress made since that paper was written. The indicator-diagrams showed how great an improvement had been made. He thought that some of the members who had modern winding-engines, working under ordinary circumstances, might be able to show a diagram similar to Fig. 1, but he was afraid that those who had an engine designed to work with steam at a pressure of 40 pounds, and which was working at 80 pounds, would find a diagram like Fig. 2, when turned upside down.

Mr. T. M. FAVELL said that the members were told that the actual amount of steam used when the gear was not in operation was 2,876 cubic feet, and when the gear was in operation it was 1,435 cubic feet, showing a saving of 40 per cent. He did not think that the figures included the amount wasted in clearance, which would reduce the saving to 35 per cent. As to the actual economy of one fireman, he thought that more definite information might be given as to the coal-saving. It would be desirable to test the saving of fuel; they might use so many boilers two days for winding and certain boilers for other purposes, and work the winding-engine on one day with the cut-off gear in action, and on another day with the gear out of action. It was an interesting matter, and worth the trouble of trying. Further, the winding-engine was intended to be compounded, and if a further test were made afterwards, the members would have three important points determined: (*a*) The consumption under ordinary circumstances; (*b*) the consumption with the cut-off gear; and (*c*) the results obtained after the addition of the compounding and condensing appliances. Although it would cost a little money and trouble to make these experiments, he thought that they would be well spent, and would yield exceedingly useful information.

Mr. J. J. PREST suggested that the author should supply a diagram showing the load, and the steam-power at each revolution of the winding-drum, with the expansion-gear and without it. The members would then be able to form a more graphic idea of the relative consumption of steam under varying conditions of load. As to the alleged extra consumption of 100 tons of slack without the expansion-gear, unless the back pressure was abnormal, he did not see how the consumption of a lessened quantity of slack would increase the production. It was stated that there was 100 tons less output with a larger consumption of fuel. There

* *Trans.*, vol. xxv., page 201.

must be something local to account for that; else there must have been a huge amount of back pressure when the expansion-gear was not at work.

Mr. FAVELL said he read that statement differently from Mr. Prest. He understood that the output was 100 tons less, because they could not supply sufficient steam to the winding-engine, with the firemen they had at the boilers.

Mr. PREST said they could not take it as a general principle that because 100 tons were lost under certain conditions, that it would therefore be lost under all circumstances.

Mr. WM. HEATH stated that since the cut-off gear had been attached to the winding-engine, an inferior quality of slack had been used; and one man less had been employed in the fire-holes. He did not think that they would be able to furnish the particulars asked for by Mr. Favell and others. But engineers connected with collieries would understand that the quality of fuel used was so different that it was almost impossible to arrive at exact figures. With respect to the lessened quantity of coal drawn on the day when the cut-off was out of operation, that could easily be understood. As Mr. Cowlishaw had mentioned, steam could not be maintained to keep the engine going at its proper speed. The engines took out, by suction, a considerable amount of water from the boilers, necessitating the introduction of a larger amount of cold water, and the use of more fuel to maintain the production of steam. This fact, coupled with the back-pressure, would account for less coal being drawn, and more coal being burnt at the same time.

Mr. FAVELL said that his suggestion was to make an experiment with the cut-off gear off on one day and in action on another day. He appreciated the difficulty of ascertaining and comparing what was done now compared with what was done six or eight months ago.

Mr. WM. HEATH said that it might be tried as Mr. Favell suggested, and the same kind of fuel used on each day of the experiments.

The PRESIDENT asked what proportion of fuel was consumed to the fuel raised, what was the percentage in weight?

Mr. HEATH observed that the President asked what amount of fuel was used in proportion to the amount of output. That would be a very difficult thing to ascertain, because there were two other winding-engines worked from the same boilers; so that it would be difficult to ascertain what steam was taken for that particular winding-engine.

The PRESIDENT remarked that they were working much the same every day, and the difference made in the total would represent the saving or loss by the use or disuse of the expansion-gear.

Mr. WM. HEATH said that they could ascertain the difference by assuming the other winding-engines to use the same proportion of steam one day as another, and so obtain an approximate result.

Mr. A. HASSAM said that he should like to know whether the indicator-diagram, Fig. 1, compared favourably with other winding-engines, or whether another type of valve would not reduce the back pressure ?

Mr. WOODWORTH said that the two indicator-diagrams (Figs. 1 and 2) were a fair comparison one with another. Since they were taken, the water-heater had been removed and the indicator-diagram, Fig. 1, if repeated now would be a little better, and would favourably compare with that obtained from many winding-engines. With regard to the paper by Mr. Daglish, to which the President had referred, there had been many attempts to work winding-engines expansively, but he was sorry to say that many of them were practically failures. His (Mr. Woodworth's) object had been to try to overcome the practical difficulties, and to approach as near theoretical perfection as possible. In all trip-gear arrangements, the cut-off must take place before the main valve had completed its lift or travel, and that was never beyond 25 per cent. of the stroke. That was too early for practical use in ninety cases out of a hundred. The Woodworth gear was so arranged that it could cut-off as late as 65 per cent. of the stroke, and cut-off shorter and shorter every revolution, and so overcome that difficulty. In the Sneyd winding-engine, the slide-valves and the cut-off valve were built to suit the valve-boxes already in existence, so that the indicator-diagram was not as perfect as it would have been had new valves and boxes been used. Mr. Heath would be able to state the saving after further experiments had been made. Experiments might be made for a day with the cut-off and a day without it, and they would tend to fully elucidate the question. The 100 tons of loss of output was owing to the inability to maintain the steam-pressure, and to increased priming when working in full gear. The members would recollect a paper which he read some nine or ten years ago on the same subject, showing what could be done with economy and efficiency. This paper referred to the action of a fixed cut-off, so arranged as to suit its respective sphere of work, and it was not until the last three or four years that he began to study progressive action as being the most suitable for winding-engines, and his ideas had been carried out in the arrangements at Sneyd colliery.

Mr. LOCKETT supposed that Mr. Heath took the percentages of consumption before the Woodworth cut-off gear was applied to the winding-engine. If so, he would have an idea as to the percentage of saving, and it would be a guide as to the effect of applying the gear by showing what the saving had been.

Mr. WM. HEATH said that they might have been a little remiss at Sneyd colliery, as they had never ascertained the actual amount of slack consumed.

Mr. COWLISHAW said that the consumption of steam was measured on the diagram, and the clearance was not taken into account When the clearances are taken into account, the saving would be reduced to about 37½ per cent.

Mr. WOODWORTH thought that in estimating the clearance and giving a liberal allowance for steam used in landing, the total saving would remain in volume as before, but the relative proportion would be reduced probably by 4 or 5 per cent. of the total steam consumption. The admission of steam was rather limited in the winding-engine: the indicator-diagram, Fig. 1, showed a continuous fall of steam-pressure as the speed increased throughout the whole of the winding, and Fig. 2 showed the fall to the same extent in the first four revolutions in full-gear working. But when the cut-off came into action the steam-admission line was increased, although the speed was increasing, as the steam supply then was all confined to one or the other cylinder alternately, instead of both taking steam together for some portion of the time: consequently, the initial pressure in the cylinder was maintained at a higher level throughout.

Mr. COLE moved, and Mr. LOCKETT seconded, a vote of thanks to Mr. Cowlishaw for his paper, and the discussion was adjourned.

The meeting was then closed.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, MARCH 14TH, 1896.

MR. JOHN NEVIN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated.

MEMBERS—

Mr. WALTER EDWARD HEADLEY, Civil and Mining Engineer, 1, Albion Place, Leeds.

Mr. STEPHEN HARRISON, Colliery Manager, Kinsley, Hemsworth.

Mr. R. SHEARD, Mechanical Engineer, Calder Vale Boiler Works, Wakefield.

ASSOCIATES—

Mr. GEORGE CROSBY, Colliery Under-manager, Featherstone, Pontefract.

Mr. JOHN MINNIKIN, Colliery Underviewer, Ivy Cottages, Hoyland Common, Barnsley.

Mr. SHADRACK STEPHENSON, Colliery Under-manager, Fleackingly Beck, Woodlesford, Leeds.

Mr. JAMES WALTON, Colliery Under-manager, Darfield Main Colliery, Barnsley.

STUDENT—

Mr. ALFRED BRADLEY SOUTHALL, Jun., Mining Student, Monckton, Barnsley.

Mr. H. WORMALD read the following paper on "Adjustable Piston-rings":—

ADJUSTABLE PISTON-RINGS.

By H. WORMALD.

The system of adjustment of piston-rings referred to in this paper is the invention of the writer, who claims that it is more efficient than any of the methods now in use. The object of a piston-ring is to prevent slip of steam or water past the piston when working, to keep the piston at its full duty, and to prevent waste of steam.

The writer is well aware that he is treading on ground that has been trodden by different inventors of adjustable piston-rings, with the object of attaining a perfectly steam-tight joint between the piston and the sides of the cylinder. All engineers who have trodden this ground are more or less aware that piston-rings become defective after working for some time, according to the pressure exerted against them or against which they are forcing, the great pressures being those under which they are likely to give the worst results.

Figs. 1 to 7 (Plate X.) show the application of Wormald piston-rings to cylinders up to 16 inches in diameter or thereabouts. The same type of rings and packings are applicable to larger diameters, in which case the junk-ring *D* would be secured to the piston-body *E* in the usual way, that is by a number of bolts (proportionate to the diameter of piston) for holding the junk-ring firmly in position to the piston-body in addition to the nut on the piston-rod.

The outer rings *A A* (Fig. 1) are of the usual shape, turned and cut in the ordinary way, spring being allowed for, so that they may move outward of their own accord to fit the body of cylinder as they become worn (if they will do so). Practice has revealed to engineers using piston-rings that they do not move out as desired or as theoretically allowed for, hence some means of adjustment is required to make them fit the body of the cylinder. The Wormald piston-ring accomplishes this result, and the rings remain in as effective working order when they are almost worn out as they are when new. They possess the further advantage of wearing the cylinder-bodies equally at all parts of the circumference.

When the piston-rings *A A* are worn and new ones are required, the central rings *B B* and the packing-rings *C C* are used over again, and simply placed in the first position (Fig. 1) in which new rings are placed as when the piston was new. When the piston-rings are new they present the appearance shown in Fig. 1, and as they become worn the different degrees of adjustment are shown in Figs. 2, 3, 4, 5, and 6. It will be seen that the whole of the packing-rings form one solid block after setting in position, and there is no possibility of the main piston-rings *A A* being compressed inward as they rest upon the packing-rings *B B*. The piston-rings *A A* are at liberty to move outward of their own accord as a consequence of any spring that may be left in them, in the same manner as any other type of piston-ring is at liberty to move outward.

Some of the ordinary types of piston-rings in common use are shown in Figs. 8, 9, 10, 11, 12, 13, and 14 (Plate X.), none of which possess any means of adjustment. Fig. 8 shows the solid-block type of piston-ring; Fig. 9 (Plate X.) is the Ramsbottom type; Figs. 10 and 11 illustrate the single metallic-ring type; Fig. 12 is the double metallic-ring type; Fig. 13 (Plate X.) is the spiral coil-ring; and Fig. 14 is the Goodfellow piston-ring.

Members are doubtless acquainted with these different types of piston-rings, and from the illustrations it will be seen that these possess no means of adjustment beyond any spring that they may possess when newly fixed, and which the author considers amounts to little or nothing in the vast majority of cases after working for a short time. This class of piston-rings becomes useless after working for some time, and the steam or water slips past the body of piston as though no rings were in use; in many cases these piston-rings are practically of no use, when first inserted.

At the present time some makers of piston-rings (knowing the uselessness of depending upon spring in piston-rings of small diameter having no adjustment) provide only a solid ring to fit the cylinder (Fig. 8). Such a ring becomes useless after about a month's wear, it is then replaced by a new one, and so the process goes on of providing a new ring every month or so.

The practical applications of the Wormald piston-ring have been as follows:—A new piston, 14 inches in diameter, fitted with a Wormald adjustable piston-ring, was applied to an engine in a brickworks, in lieu of a piston fitted with a ring similar to that shown in Fig. 12. Without any increase of labour or of fuel, or of the hours being worked daily, the plant made 700 bricks per day more, or an average of say 4,000 more bricks per week, and the saving amounted to about £200 per annum.

Another practical application of the Wormald piston-ring was made to a vertical engine working a dirt-tippler on a colliery refuse-heap, the cylinder being fitted with the same type of piston as that illustrated in Fig. 12. The work done by this engine was all on the bottom side of the piston, whose top side was left open to the atmosphere. When working with the ordinary piston-rings (Fig. 12) the steam rushed past the piston and blew out in all directions, but when the Wormald piston-ring was inserted (Fig. 1), this escape of steam was stopped, and there was no leakage showing that the piston was steam-tight.

At the same works, different types of pump-pistons have been replaced by pistons fitted with Wormald piston-rings, in all cases with satisfactory results, and far superior to those obtained when engines were working with piston-rings having no adjustment.

Mr. H. WORMALD, replying to questions, said that the cylinder-cover was removed in order to adjust the Wormald piston-rings, which are not self-acting. Fig. 6 showed the rings *A* when they are worn out; and when the packing-rings *B* were all brought inside, it showed the amount of wear on the piston-rings *A*. If the cylinder itself wore away, as it would in time, the piston-rings could be made a little thicker, and thus compensate for the wearing away of the cylinder. The cost was small, but as it included the patentee's rights, it appeared rather higher than usual. The wear of a horizontal cylinder was greater than in any other. Adjustable piston-rings were suitable in such cases, because all other piston-rings were loose, and would give way with the wearing of the cylinder. With an ordinary engine, working twelve hours a day, at 500 feet of piston speed per minute, the automatic piston-rings should last about two years.

Mr. DAVID BANNISTER said he was inclined to think, after working six or seven months, that the rings would get a little side-play and continuing to work in that position for a few weeks, the effects of the hammering action which would take place at each end of the stroke, would cause the recess in the piston-body to become worn a little wider. The play would then be taken up, the rings expanded and recommence to work at a larger diameter and might work satisfactorily for a similar

The Federate

"piston rings."

Vol. XI Plate X

Fig. 13.

Fig. 14.

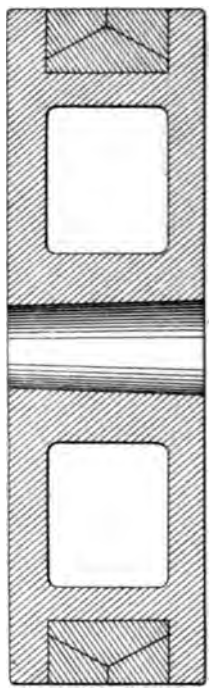


Fig. 11.

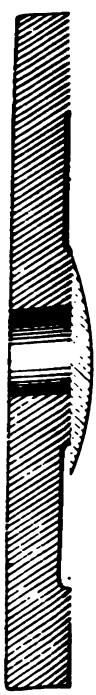
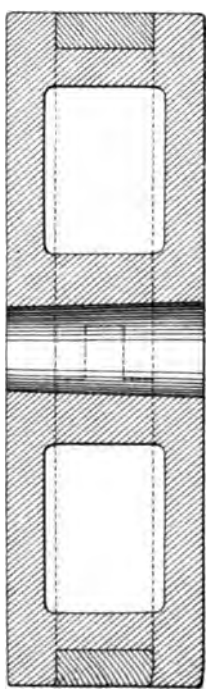
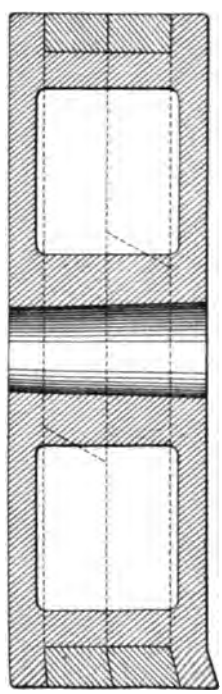


Fig. 12.





Midland Ind

Vol XIV. Plate VIII.

Another practical application of the Wormald piston-ring was made to a vertical engine working a dirt-tippler on a colliery refuse-heap, the cylinder being fitted with the same type of piston as that illustrated in Fig. 12. The work done by this engine was all on the bottom side of the piston, whose top side was left open to the atmosphere. When working with the ordinary piston-rings (Fig. 12) the steam rushed past the piston and blew out in all directions, but when the Wormald piston-ring was inserted (Fig. 1), this escape of steam was stopped, and there was no leakage showing that the piston was steam-tight.

At the same works, different types of pump-pistons have been replaced by pistons fitted with Wormald piston-rings, in all cases with satisfactory results, and far superior to those obtained when engines were working with piston-rings having no adjustment.

Mr. H. WORMALD, replying to questions, said that the cylinder-cover was removed in order to adjust the Wormald piston-rings, which are not self-acting. Fig. 6 showed the rings *A* when they are worn out; and when the packing-rings *B* were all brought inside, it showed the amount of wear on the piston-rings *A*. If the cylinder itself wore away, as it would in time, the piston-rings could be made a little thicker, and thus compensate for the wearing away of the cylinder. The cost was small, but as it included the patentee's rights, it appeared rather higher than usual. The wear of a horizontal cylinder was greater than in any other. Adjustable piston-rings were suitable in such cases, because all other piston-rings were loose, and would give way with the wearing of the cylinder. With an ordinary engine, working twelve hours a day, at 500 feet of piston speed per minute, the automatic piston-rings should last about two years.

Mr. DAVID BANNISTER said he was inclined to think, after working six or seven months, that the rings would get a little side-play and continuing to work in that position for a few weeks, the effects of the hammering action which would take place at each end of the stroke, would cause the recess in the piston-body to become worn a little wider. The play would then be taken up, the rings expanded and recommence to work at a larger diameter and might work satisfactorily for a similar

a. 13.

Fig. 14.

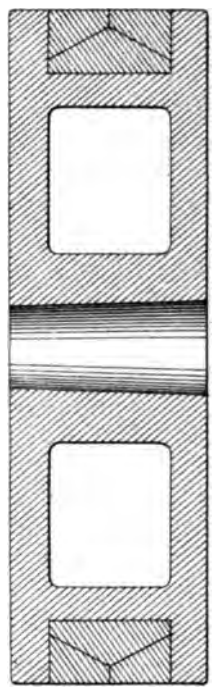


Fig. 11.

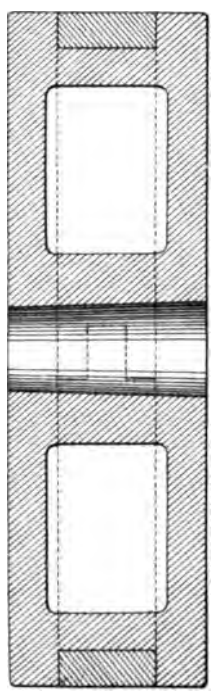
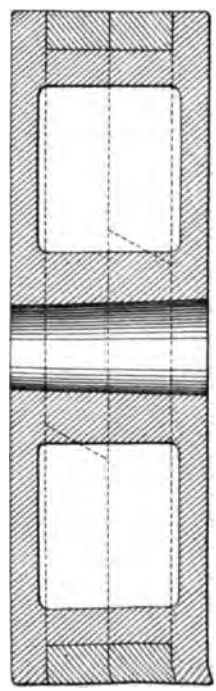
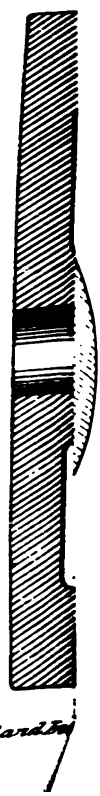


Fig. 12.





Midland Ry

period. Then the same action would take place and form another ring or step on the piston-body, but of a larger diameter than the first one; and thus the process would continue until the rings were worn out, and would form a number of steps on the recess in the piston-body. He asked Mr. Wormald to tell the members how new rings could be made, fitted upon the old body and made steam tight?

Mr. WORMALD said that there might be a step on the piston body, but he hardly thought so. If there was, it would be a simple matter to turn the steps down in the lathe. If there were steps on the piston-rings, as would be most likely, they would pass away with the discarded rings.

Mr. BANNISTER said that the piston might be a considerable distance from a lathe, and it might be a greater expense taking the piston to the lathe than putting in new piston-rings.

Mr. WORMALD said that the automatic piston-rings had been working for twelve months at the Ackton Hall collieries, and he had experienced no difficulties whatever in their use.

Mr. ATKINSON asked whether the piston-rings had been taken out and examined?

Mr. WORMALD replied that the piston-rings had been taken out in order to change the adjustment—one packing ring from the outside to the centre in each case. He thought that if any difficulty occurred it could be easily overcome.

Mr. ROUTLEDGE proposed that the thanks of the meeting be given to Mr. Wormald for his paper.

Mr. NASH seconded the motion, which was agreed to.

DISCUSSION ON PROF. LEWES' PAPER ON "MINING EXPLOSIVES."*

The PRESIDENT said that the point which Prof. Lewes pressed most was in regard to the products of combustion of various explosives, and affirmed that the best explosive was that one in which the products of ignition contained no combustible gases.

* *Trans. Fed. Inst.*, vol. ix., page 320; and vol. x., page 454.

Mr. NASH said that Prof. Lewes was of opinion that traces of carbon monoxide, the product of the combustion of an high explosive, would, when present in such minute quantities as to form a mixture far removed from the point of explosion, render a mixture of coal-dust and air highly explosive.

The PRESIDENT said that the result of Prof. Lewes' theory was very much in favour of the use of nitrate-of-ammonium explosives (roburite, ammonite, and bellite). Prof. Lewes condemned the use of blasting-powder, gun-cotton, blasting-gelatine, and carbonite.

The discussion was adjourned.

DISCUSSION ON MR. ALEX. REID'S PAPER ON "METHODS OF CLOSING THE TOPS OF UPCAST WINDING SHAFTS."*

Mr. BONSER (Leeds) said that he had never seen the top of an upcast winding-shaft to which they should not attach a safety-hook. He believed that the effect of such a contrivance as was described by Mr. Reid in his paper, would be to prevent the efficient working of any ordinary detaching-hook at an upcast pit. He thought that some inventive genius might provide an upcast pit-top so that a detaching-hook could be used.

Mr. WM. HARGREAVES (Rothwell Haigh) said, in connexion with the winding at the upcast pit at Thrybergh Hall colliery, that they had Mr. Reid's arrangement, with a little variation. The ascending cage entered a closed box, and the detaching-hook, chains, and shackles entered a lesser door which the cage lifted up. When the cage passed these doors, it was in a box which practically sealed the shaft, and they found little difference in the air-current. They wound 800 tons a day at Thrybergh Hall colliery, where this system was in use, and had never had any difficulty or accident. At another pit they banked into an air-tight chamber. They had to open two doors in a chamber which was fixed away from the pit, in order to pass the tubs to the screens, and the banking was very costly, whilst they did not find any better results than with the Reid arrangement. There was no difficulty in providing for the use of a detaching-hook. The smaller door for the detaching-hook, etc.,

* *Trans. Fed. Inst.*, vol. x., page 367.

was lifted first. The cage had been overwound both purposely and accidentally, and no difficulty had been experienced with the detaching-hook. The smaller door was very light, and if the cage was overwound the door was broken before the detaching-hook reached the point at which it acted.

Mr. R. ROUTLEDGE (Garforth colliery) said that the arrangement at Garforth was similar to that described by Mr. Reid. Their engineman had overwound the cage two or three times. There was an arrangement on the top side of the door which allowed it to fall into two pieces.

Mr. HARGREAVES said that the arrangement had worked satisfactorily for eight years, and replied that the smaller door was made of wood 18 inches in diameter and $\frac{3}{4}$ inch thick.

Mr. BONSER said that there was a new Mines Bill before the House of Commons, and he had no doubt that the Council of the Institute would consider it before it was passed into law. He believed that there would be embodied in the bill clauses which would bring the metalliferous mines under the same Act. Metalliferous mines were generally without these appliances; if they were brought under the Mines Act and had to provide this apparatus, any information on the point would be most useful to the members of the Institute. The subject that he mentioned with regard to the detaching-hook was this—was it possible, in the act of raising the rope through the ventilation-doors at each winding, to disengage the hook and let the cage go down the pit? He thought that the members would find that there were few detaching-hooks used at closed upcast pits, owing to the risk of detaching the cage in the ordinary routine of working.

Mr. ROUTLEDGE said that the Ormerod hook was used at the Garforth collieries, and the small door could not get into the bell.

Mr. T. W. H. MITCHELL said that he thought Mr. Bonser was under a wrong impression in respect to the doors. His (Mr. Bonser's) impression seemed to be that the detaching-hook was constantly running through a narrow space, so rendering it liable to be cut off. The rope and capel took the covering-box up with it, it ran through the pit top covering-box which was the size of the cage itself, and it never went near the detaching-hook at all. The little door was placed 4 or 5 feet above the detaching-hook, when it was in the air.

Mr. BANNISTER said that there was some risk of the small door when broken being carried into the bell-shaped detaching-plate. In a trial, to lift the cage gently up to the bell-casting in the head-gear the small

pieces of timber had time to fall away; and he asked whether by an overwinding, the wooden-door had been driven into the bell?

Mr. ROUTLEDGE said that four overwindings had occurred at Garforth collieries, and the hooks had caught and suspended the cage on each occasion.

Mr. BANNISTER asked whether the winding engine at the time of overwinding had been going at almost the speed it would travel in the middle of the shaft, or had it been in the act of stopping and had the cage gone a few feet too far?

Mr. ROUTLEDGE said that they had been drawing coal, and the cage would not be going as fast as in the middle of the winding, but faster than under ordinary circumstances.

Mr. HARGREAVES said that he had known a workman start the winding-engine the wrong way, and the cage was detached as easily as if there was nothing in the way. In the case of the King detaching-hook at Houghton Main colliery, the speed at which it was going damaged the plate.

Mr. WORMALD said that in regard to these safety-hooks and covering-boards it did not matter whose hook was used. As the hook went up it would carry the covering-board, and it did not strike the door in any part that struck the disconnecting bell.

The discussion was then closed.

DISCUSSION ON MR. A. W. BENNETT'S PAPER ON "TELEPHONIC COMMUNICATIONS IN AND ABOUT COAL-MINES."*

Mr. BENNETT said that the Stead carbon-ball transmitter was used at Aldwarke collieries, and they gave every satisfaction. A very similar transmitter, the Berthon, was used for conversation between London and Paris.

The PRESIDENT said that a system of covered endless-wire could not be used as ordinary telephone wires were occasionally used. A work-

* *Trans. Fed. Inst.*, vol. x., page 372.

man could not carry a telephone in his pocket and attach it to any part of the wires and communicate with the bottom of the pit, or any other part of the mine.

Mr. BENNETT said that a pair of wires could be laid from any of the stations, and there would be no difficulty in attaching pocket-telephones to these wires.

Mr. NASH asked whether that would not be more expensive than the present system?

Mr. BENNETT replied that it certainly would be so. The system described in his paper was intended for use in mines where there were a large number of stations. In small collieries, a telephone with one wire would be the simplest system.

The discussion was then closed.

DISCUSSION ON MR. RANKIN KENNEDY'S PAPER ON "ELECTRICAL MACHINERY FOR MINES."*

Mr. BENNETT desired to emphasize Mr. Kennedy's remarks as to using polyphase-current motors in mines; they had no commutators or brushes, were sparkless, and did not require to be enclosed. Mr. Kennedy advocated the use of dynamos producing different kinds of electric current, and it seemed to him that an arrangement for producing polyphase currents would be of great service for working colliery machinery.

Mr. NASH asked whether polyphase dynamos and motors had not been recently developed, and whether their possibilities were not as yet unknown?

Mr. BENNETT said that polyphase motors had not been used in England because engineers were not conversant with them.

Mr. NASH remarked that that was the fault of the electrical engineer.

Mr. KENNEDY said that two polyphase motors were in use, and in a short time a coal-cutting machine would be running with a two-phase motor.

Mr. NASH asked where in an actual electrical installation they wished to introduce a polyphase motor for pumping, etc., whether it would necessitate a rearrangement of the dynamo on the surface?

* *Trans. Fed. Inst.*, vol. x., pages 98 and 457.

Mr. KENNEDY said that a dynamo running at a high speed could be altered so as to yield polyphase current at a small cost. With an ordinary 100 or 110 volts dynamo, the current could not be carried any distance without considerable loss, or the use of heavy wires, but if the machine were converted to yield polyphase current the pressure could be raised or lowered without much loss—not exceeding 10 per cent.—for a distance of 10 miles. The pressure could be raised to 10,000 volts, and re-lowered to 100 volts, so that an ordinary telephone wire would transmit 50 horse-power.

The discussion was adjourned.

The meeting was then closed.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD IN THE MUNICIPAL SCIENCE COLLEGE, DERBY, APRIL 4TH, 1896.

MR. GEORGE LEWIS, PAST-PRESIDENT, IN THE CHAIR.

The following gentleman was elected :—

ASSOCIATE —

Mr. WILLIAM WESLEY FINCH, Conisborough, Rotherham.

The SECRETARY gave notice on behalf of the Council for alteration of Article 1, Section VI., of the Rules to read as follows :—

There shall be three Ordinary General Meetings in each year, to be held in Chesterfield, unless elsewhere arranged for by the Council, in every April, August, and December, the meetings in April and December to be on the first Saturday in the month at 2·30 p.m., and the date of the meeting in August, which shall be the Annual General Meeting, to be fixed by the Council. Anything in the rules affected by the foregoing intended alteration to be adjusted accordingly.

The SECRETARY read the balloting-list prepared by the Council for the election of officers for the year 1896-97.

The SECRETARY read the following paper on "How a Mine may be Dry but not Dusty," by Mr. George Fowler, of Nottingham :—

HOW A MINE MAY BE DRY BUT NOT DUSTY.

By GEORGE FOWLER, M. Inst. C.E.

The growing conviction that many colliery explosions, if not originating in the explosion of coal-dust, have at all events been greatly intensified thereby, has made the dust problem one of the most important to the mining profession and to the legislature. There can be no doubt that the next Coal Mines Regulation Bill will contain an attempt to grapple with this question in as thorough a manner as the knowledge and experience at our disposal are capable of doing. If this information be insufficient or the deductions from it erroneous, it is possible that much harm may be done.

In the writer's judgment, the drift of professional opinion is too much in favour of one line of treatment and of one remedy. It is with the view of suggesting other remedies that these notes are offered for the consideration of the members of this Institution.

The questions which the writer would like to place before mining engineers, before they advocate and then adopt the various methods of watering dust which are before the public, are :—(1) Is it possible to minimize what may be termed the production of dust? (2) Is it possible to remove it or the greater part of it by a dry method?

Let us first deal with the production of coal-dust in a modern long-wall colliery. The roadways are now nearly wholly made through the rock and shales of the strata overlying the coal-seam. The dust of these strata is earthy, incombustible, and not in itself a cause of danger. When we reach the working-faces, we for the first time come into contact with the coal *in situ*. The ordinary work connected with the hewing and loading of the coal does undoubtedly make dust, and the very finest of this is no doubt carried more or less by the ventilation into the return-airways of the mine.

The dust found on the main haulage-roads of the mine is produced either by dust blown by the ventilation from the loaded waggons, by dust blown by the ventilation from empty waggons, or by coal falling from the waggons and crushed either by the feet of men or horses. It is the opinion of the writer that this is the main source of dust in coal-

mines. He is also of opinion that in a large number of cases the dust is thus produced in needless abundance, and that it is possible to introduce changes in the conveyance of coal to the pit-bottom, which will make the dust problem one of easy solution.

With a view of ascertaining the amount of dust deposited on the roof and sides of a large colliery, the writer has made numerous measurements of the actual thickness of dust deposited in one district of the Cinder Hill colliery. It may be premised that this colliery was sunk nearly fifty years ago; that its workings are perfectly dry; that the production of coal from it during that period has reached nearly 10,000,000 tons; and that the district from which the plan (Fig. 1, Plate XI.) is copied has been in work at least thirty years. It has not been possible to exactly measure the thickness of dust deposited on the intake airways, but the author's estimate is that on timber and sloping sides the dust from the pit-bottom along the engine-plane may be estimated to be ½ inch in thickness, or would have been if it had not been removed. On the engine-bank from *A* to *B* (1½ miles), the thickness of dust in the same manner may be taken as shown in figures on the plan. This has also at various times been removed, so that the quantity in the roadway does not now exceed a film of, say, ¼ inch in thickness on the sides and roof.

In the return-airways, no attempt has ever been made to remove the dust, and the measurements there made represent the maximum collecting power of the roof, timbers, and sides of the airways, during the thirty years or so in which this airway has carried 40,000 or 50,000 cubic feet of air per minute.

It will be noticed that the film of dust is insignificant for 900 feet back from the face; this represents the distance worked in three years; and shows that for that length of time the collection of dust is insignificant. At a greater distance from the face, in the airway, at the points *D*, *E*, and *F* the dust is a good deal blacker than the rest, and it represents a period of years during which the workmen worked with flaming torch lamps, which gave off a considerable quantity of smoke. This period of working is very clearly shown on the sides of the return-airway.

Nearer the shaft, the thickness of dust increases, and in some cases it measured 1 inch in thickness, and so far as the writer knows is the aggregate collection of thirty years of use. Allowing for portions to which dust does not adhere, and for dust lodged on timber, the writer's estimate is that this airway, which measures 10,500 feet from the face to the upcast shaft, contains at the present moment only 5,400 cubic feet of dust, and

that this represents the undisturbed collecting power of the airway for thirty years. It is easily reckoned from this that the daily collection of dust does not exceed ½ cubic foot.

This dust is the dust from dry and dusty working-faces; and is in no sense the dust arising from the conveyance of the coal to the bottom of the shaft. With reference to this branch of the subject, the writer must now premise that he considers the conditions, for reasons which he will give later, are exceedingly favourable to a slight deposition of dust. He is under the impression that the maximum thickness of dust, if it had never been disturbed, upon roof timber and upon convenient ledges on the level engine-plane, from *C* to *A* would not exceed 1 inch at the present moment, although this road has been in operation for forty years. He considers that on the engine-bank from *A* to the working-faces, at the upper end ¾ inch, half-way down ¼ inch, and 1,500 feet from the working-faces a mere film, is all that would have collected had no dust ever been removed.

The writer must here call attention to the fact that he is speaking only of the roof and sides, and that he will deal with the floor in another way. Confining his attention to these points the writer's opinion is that the outside estimate for the possible collection of dust on the roof and sides would have been for the first 3,600 feet, a maximum of 10,800 cubic feet, over a period of forty years; or a daily collection of not exceeding 1 cubic foot.

It now becomes of interest to investigate why this quantity of dust is so small. And in the first place, as already referred to, there can be no doubt that the roads, being primarily made in the rock-roof, yield little or no carbonaceous dust themselves; and that for hundreds of feet back from the working-faces the only dust is a grey dust, the colour of Portland cement.

The dust, therefore, that is made in these roads comes entirely from the dust caused by the haulage of coal; and here the writer would point out why the conditions are so favourable for the non-production of dust. In the first place, the pit-waggons at this colliery are close-ended wooden waggons; secondly, they are emptied at the pit-top by being turned over in revolving-tipplers; in the third place, the haulage is entirely done by machinery.

There are no horses to trample up and crush any coal which may fall off the waggons. So far as can be ascertained, it appears that the coal which does fall off does not exceed ¾ per cent. per day of the coal drawn, and this coal is nearly all picked up in lumps and sent to bank. It is

only in turn-outs or bank-heads that any crushing to dust can very readily take place. The little dust that is produced comes mainly from that which the ventilation blows from the loaded waggons. For, as already pointed out, the empty waggons are completely tipped over and emptied of dust at the pit-top.

The first practical inference, therefore, which the writer would like to draw is that all forms of open-ended waggons, or lattice-framed waggons, are highly objectionable. It is a matter of common knowledge that many of the collieries in the Midland counties use an open-ended pit-waggon. In South Wales, an iron cagework on wheels is the vehicle adopted for the conveyance of coal underground. Both of these must be followed by quite a train of small coals on their journey to the pit-bottom, and must produce clouds of dust. Thus the first step for the prevention of dust is to have a close-ended waggon.

The next inference the writer would draw is that this waggon should be fairly tipped over at the pit-top. He would go further, and suggest that every empty waggon should be thoroughly blown out with a small fan-blast, before being sent down the pit, as he is of opinion that in many cases the imperfectly-emptied waggon produces as much dust as the loaded one.

Having briefly dealt with the accumulation of dust in a large and old colliery, where the conditions for the conveyance of coal from the working-faces to the pit-bottom are highly favourable for the prevention of waste by the way—which the writer believes to be the main cause of the dangerously dusty mine, and which he believes is the reason why this mine in question is so remarkably free from dust—the writer now desires to call the attention of the members of the Institution to the conditions which are most favourable to the prevention of the deposition of dust on the roof and sides of a mine ; and to its easy removal.

He has already shown that in the mine in question the stall-gates, and roads back from the faces, say for 900 feet, show no appreciable coating of carbonaceous dust on the sides of roads, and upon roof timbers; and that this non-dusty portion represents three years of coal-getting. It therefore follows that, as in the method of working adopted in this colliery the stall-gates are cut off every two and a half years, none of these require serious consideration in dealing with the possibility of dangerous accumulations of dust.

Though the panel of workings, of which the plan (Fig. 1, Plate XI.) is an approximate copy, represents a haulage distance of $2\frac{1}{2}$ miles from the working-faces to the drawing shafts, yet it is the opinion of the writer that

this large colliery, with the capacity for production of 500,000 tons per annum, has only 4 or 5 miles of haulage-way on which special precautions are necessary to prevent the dangerous qualities of coal-dust from becoming potential. He has already shown that the quantity of dust, even when an accumulation of years is probable, is small; and the question he would like to lay before the members of the Institution is, is it not possible (instead of schemes of water-pipes and water-jets, which are very costly to install, which are very costly to use, and which he will later on point out are very objectionable to use) in the first place so to construct the roadways that the accumulation of dust may be still less than in the case described he has shown it to be? And when he has done this, he will desire to be permitted to ask whether what may be called "the treatment per housemaid," to wit, the occasional sweeping with a broom of dusty portions, may not make the roofs and sides of the mines free from dangerous accumulations of carbonaceous dust?

With a view to testing this point, he has specially prepared two portions of a roadway of this colliery of a total length of 1,500 feet, so that the sides and roof are smooth and easily swept, and the diagram (Fig. 2, Plate XI.) shows its general appearance. Where the roof is timbered, and the roadsides are packed, these packs have been plastered with mortar, until the surfaces are smooth and not dust-collecting, and the cost of this operation is found to be 1½d. per square foot. Where the binds are strong, they have been slightly trimmed with the pick at a cost of 1d. per square foot.

It will be observed that a thin coal-seam runs along some part of the roadway. This has been trimmed in a similar manner, and at about the same cost. On the upper edge of this thin coal-band are 5 or 6 inches of very weak binds, which are apt to shell off, and leave a little shelf of dust-collecting capacity. This little shelf has been plastered up like the packs, and ceases to perform that function. Below the thin coal-seam are the original bind-packs of the working-face. These have been squared up and plastered smooth, or underbuilt with stone, and the whole sides of the roadway, measuring 1,500 feet in length, have been made smooth at a cost of 10d. per lineal foot.

We now come to the practical problems which arise in dealing in the same manner with the roof. For considerable distances this is a fairly strong bind, requiring only occasional bars, and providing small opportunities for the collection of dust. But in other places this rock is broken and is barred, and these bars have slabs placed across them to prevent loose pieces of roof from falling down. It must be admitted that these irregular slabs, and these fractured rocks, present facilities for the

accumulation of dust, although, as will be shown later on, these roof-fractures will be more troublesome to the advocates of the water system than to the advocates of the dry method. In some cases, this irregular timbering may be smoothed and rendered non-dust-collecting, by careful plastering with mortar; but the writer is of opinion that in the main roads of a mine, a somewhat more systematic covering of broken roof is desirable, and would, in the long run, pay for its adoption.

Some years ago the writer put in the insight at the pit-bottom of a large colliery with steel roof-beams, and close-fitting short pieces of timber resting on the flanges of these, thus closely sealing the roadway. These have borne great weight for many years, and present no surface for the lodgment of dust. He is of opinion that the same treatment might be extended to weak and broken portions of the main roadways of the mine; that although the cost in the first instance may be a little heavy, it will pay, as a question of maintenance; and that if properly put in, and packed close with fine dirt, it will completely prevent the accumulation of dust where the roadways of the mine are tender and broken. It is also possible to arch extremely weak and bad places, and the arch again presents small surface for the collection of dust. The writer would like to point out that, in nearly all collieries, rough mortared stone walling can be built at a very moderate cost per lineal foot of road. No doubt these costs will vary somewhat in different places, but, in the mine in question, the trial portion of 1,500 feet cost altogether £75. He is of opinion that the whole 4 miles of roadway might be made smooth at sides and top for a total cost of little over £1,500; and that if it was desirable to still further illustrate the presence of small portions of dust, and to bring the roadways of a mine into what might be called a high state of dry polish, the roadways might be white-washed through from end to end at a total cost of £500.

When we have before us the figures of the enormous cost which the advocates of the wet method will incur in the first instance, in pipes and jets to saturate the air of the mine, these costs, though large, are small by comparison.

It will be observed that up to the present, the writer has made no reference to the practical dealing with the floors of the roadways; and in this matter he is prepared to be a partial advocate of the aquatic treatment. He would, however, desire to say that in turn-outs, bank-heads, pit-bottoms, and places where the waggons bump against each other, there is much to be said for brick pitching, which costs rather less than 1½d. per square foot. Further, these places should be frequently swept, and

dust and rubbish cleaned up and sent to bank or stowed away. Subject to these, and more or less general cleaning away, he is of opinion that water-tanks, with distributing-pipes under the middle of the tank, may be advantageously drawn about by ponies, or moved by the haulage-ropes; and that the main roads of a mine should have a smooth and moist surface maintained by these simple and inexpensive means.

The writer now desires to make some practical comments on the wet method of dealing with the dust of roadways, and he cannot do better in this matter than refer to Mr. Haarmann's paper on its application at the Maybach colliery in Germany.*

The first thought that strikes the writer on the perusal of this paper is the enormous first cost of the apparatus. At a colliery like the one referred to in this paper, the outlay would not be less than £20,000, and the amount of water required to saturate the sides and roof of roadways and the working-faces, would be greater than any available waters in the vicinity. Nor would this want of water be by any means uncommon in the districts adjacent to large towns, where the water-supply is greatly drawn upon for municipal purposes.

But the greatest of many objections to the aquatic treatment are, first, that in the majority of cases in this country the roofs and sides of mines will not bear to be kept constantly wetted if they are to be kept sound and upstanding. Instead of the clean, comfortable roads which are now the rule at Cinder Hill colliery, the sides and roads would be perpetually slipping, and the roof constantly requiring re-timbering, and both wooden and iron bars would suffer from the constant moisture. The contrasts between the character of the roads which are possible on the lines described by the author and those which would be the result of the Maybach treatment if fully carried out, are quite appalling to a practical miner who likes a pit in good order; and from the point of view of working cost, there is simply no comparison.

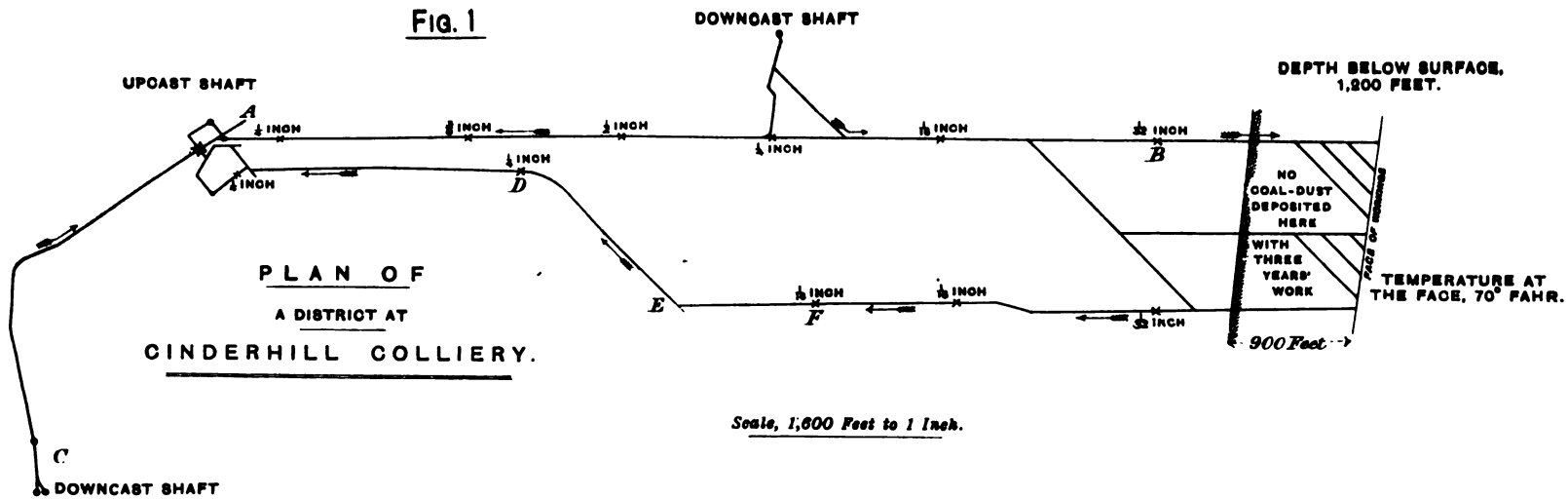
The second great objection is that a water-spray system, if it be not continuously maintained, is itself a great producer of dust. If the coal itself or the shales and rocks above coal are alternately wet and dry, a most powerful pulverizing agency has been brought into operation.

A third great objection to the spray-system lies in the injury which it is certain to cause to the health of the miner. The writer has observed more than once that where the miners work in wet places they are very subject to pneumonia and rheumatic fever It would be practically impossible if water-sprays were constantly injected into the air-currents

* *Trans. Fed. Inst.*, vol. ix., page 90.

To illustrate Mr Geo Fowler's Paper on "How a Mine may be Dry, but not Dusty."

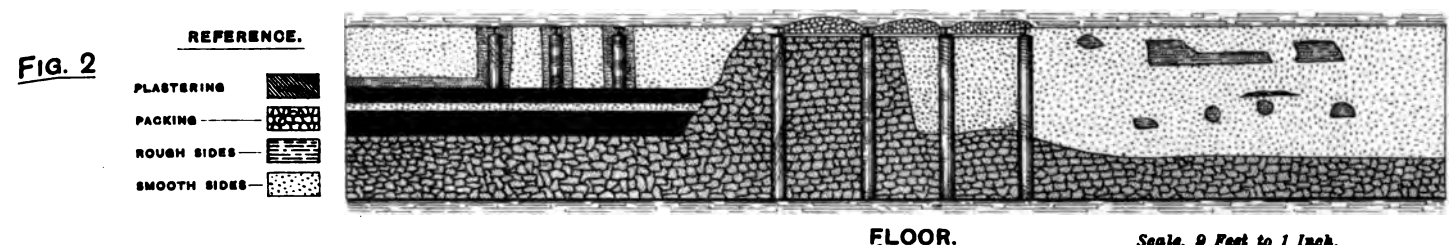
FIG. 1



Scale, 1,600 Feet to 1 Inch.

FIG. 2

LONGITUDINAL SECTION OF THE SIDE OF A GATE-ROAD.



Scale, 9 Feet to 1 Inch.

And.w Reid & Comp.y L.td Newcastle on Tyne

of mines to prevent the clothing of men being often wetted and their feet soaked at occasional puddles. In the writer's opinion, more men would die from water-sprays than now die from dust, and in this way the remedy would be only worse than the disease.

In conclusion, therefore, the writer submits that from every point of view, lessened original cost and greater efficiency, the dry method is capable of removing the unavoidable dust of coal-mines

He has ventured to point out that the attention of mining engineers should be given in the first instance to the lessening of the production of dust. Whilst open-ended waggons and lattice-framed waggons are in use, nothing else can be expected but extremely dusty roadways. By making these vehicles close-sided, and at least free from dust when empty, the production of dust will be reduced to a minimum. It is possible so to trim and smooth the sides and roofs of main roads, that the collection of dust upon them is insignificant, and the removal easy. The writer thinks that the clean and comfortable roadway, which may thus be secured for a moderate cost, will commend itself to the members of this Institution, and to those interested in mining, as a better thing than the greasy, sticky roadways, with slipping sides and with mouldy timbers, which would be the practical outcome of the aquatic treatment.

APPENDIX.

SAMPLES OF DUST COLLECTED AT CINDER HILL COLLIERY, STARTING FROM NO. 4 PIT (THE DRAWING SHAFT) INTO THE BULWELL DRIFT FACES AND BACK THROUGH THE RETURN-AIRWAY TO HEMPSHALL UPCAST PIT, ON FEBRUARY 4TH AND 5TH, 1896 (FIG. 1, PLATE XI.).

No. of Sample	Where Gathered.				Part of Road Collected from.	Thickness of Dust	Remarks.
	Distance from No. 4 Pit.	Distance from Hempshall Pit.	Distance from the Working-face.	Intake or Return.			
	Feet.	Feet.	Feet.			In.	
1	1,200	—	12,450	Intake	Bars or sides of road	1	Fine and dry, from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick on props and sides
2	4,200	—	9,450	,,	Top of bars	$\frac{1}{4}$	Top of Engine-bank (Bulwell drift)
3	5,700	—	7,950	,,	,,	$\frac{3}{8}$	Undisturbed
4	7,200	—	6,450	,,	,,	$\frac{1}{2}$	Taken at an old junction
5	8,700	—	4,950	,,	,,	$\frac{1}{4}$	Rope-road junction
6	9,300	—	3,750	,,	Top of bars and sides	$\frac{1}{16}$	Against turn-out
7	11,400	—	1,800	,,	Sides of road	$\frac{1}{32}$	Last sample in intake
8	—	9,000	1,500	Return	,,	$\frac{1}{32}$	Light, feathery, but dark in colour
9	—	7,200	3,300	,,	Bars & sides	$\frac{1}{16}$	Dark and sooty
10	—	6,000	4,500	,,	Top of bars	$\frac{1}{16}$	Sides sooty
11	—	3,300	7,200	,,	Sides of road	$\frac{1}{8}$	,,
12	—	600	9,900	,,	,,	$\frac{1}{4}$	,,

Mr. JOHN JACKSON (Clay Cross) said that Mr. Fowler was fortunate in having a colliery where simple methods would free it from coal-dust. He (Mr. Jackson) ventured to think that there were many dusty collieries in the Midland inspection district in which they would find great difficulty in applying the method that Mr. Fowler had described. It appeared somewhat extraordinary that so very small an accumulation of dust should have taken place, if nothing had been removed for thirty years. Mr. Fowler in carrying out his suggestions as to cleaning would create a certain amount of dust in the pit, and either the air-current must carry it away or allow it to fall again and accumulate. It had never been suggested that any colliery should be watered to such an extent as to make it injurious to health or to cause danger to the floor or to the sides of the road, but that a middle course should be adopted.

Mr. G. E. COKE (Nottingham) said the only method that would entirely remove the danger arising from coal-dust in mines was to stop the use of explosives in dusty places, but they had to deal with mines as they were and using explosives. He had often thought that watering was a source of danger rather than a protection. The dust was dangerous when in the air, and not when on the sides or floor. Any disturbance would cause the dust to mix with the air, and produce a dangerous condition liable to lead to explosion. He thought that in the case of Cinder Hill colliery it might be possible to render the roads clean in the way Mr. Fowler had stated, and at a moderate expense, but it had not been mentioned whether the sweeping would be done when the pit was or was not at work. He was of opinion that if the mine was swept at all during the turn, or when shots were fired, the air of the mine might be rendered more dangerous.

Mr. J. W. BARLOW (Heath) said that not generally perhaps, but certainly very often, bad repair of coal-trams was a great source of dust. The coal falling to the floor—partly through the bad condition of the loaded trams on their way to the pit-bottom—no doubt caused much of the dust. Water-spraying of the roads had advantages and disadvantages: in some collieries the watering caused upheaval of the floor, and in some cases caused probably more serious results than even the presence of coal-dust. The floor lifting caused timbers to move and falls of roof to occur. He had had considerable experience in the watering of roads in the Lancashire district, and the percentage of accidents was greater where roads were watered than where they were not watered. This subject, however, should be discussed by members

of the Institution, as it was most vital in colliery management, and he took it that every member would have something to say on a matter of this sort.

Mr. G. J. BINNS (Netherseal) said the question that presented itself to him was whether the ¼ inch, or whatever it might be that Mr. Fowler measured in a certain place, was the total dust-deposit in that place during the time when the road had been opened. He did not question the accuracy of Mr. Fowler's measurements, but he doubted very much whether this was the total deposit of dust since that road was opened. There were many causes which might arise to remove the dust from the place where it was originally deposited on to the floor. This might be even due to the passage of people in the return-airways causing a slight obstruction of the airway, and the gradual removal of the dust from the stone packs and timber-bars where it was originally deposited on to the floor. As to the dust that remained in the mine-trucks after they had been tipped, he might say that at a colliery with which he was particularly acquainted the tubs were tipped and then rushed with considerable velocity down an incline, or a switchback he might call it, and this rapid movement caused a cloud of dust to arise from the tubs after they had been through the tipplers. Mr. Fowler's suggestion that much dust was taken down the pit was probably correct, and no doubt this dust would be removed from the trams by the swift current of air in the mine, and then deposited on the sides and floor.

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) congratulated Mr. Fowler upon bringing this paper forward at the present time. Mr. Fowler headed his paper, "How a mine may be dry but not dusty." He would now like another paper written on the subject of, "How a mine may be wet and yet dusty." He was down a mine recently, which was so dusty that he could scarcely recognize himself when he came out, and yet for some distance he was walking in 1 inch or 2 inches of water on the floor, showing that there were wet mines which were dusty, as well as dry mines which were not dusty. The practical and painful illustration of the effect of coal-dust and shot-firing, which had recently occurred in this district, had again drawn attention to the accumulation of dust upon the roadways of a mine. Mr. Fowler referred to the dust of the strata above the coal as being incombustible, but probably he had not in his mind (at the time he wrote the paper) the experiments made by Sir F. Abel with silica dust, which did assist in carrying flame. The dust referred to by Mr. Fowler contained much combustible matter in the

shape of dry horse-dung and grease from the tubs. The dust on some of the roadways was in this respect as combustible as coal-dust. Mr. Binns doubted whether the ¼ inch of dust as measured was the true thickness of thirty years' accumulation on the roof and sides; this was immaterial, as recent experiments had shown that it was not the greatest quantity of dust which most readily ignited, but that explosions took place when there was less dust than in previous experiments. The first portion of Mr. Fowler's paper dealt solely with the roof and sides of mines, but when the interstices of the roof and sides were once full of dust there was no room for more. Upon the top of timber the dust would pile up in a pyramid until no more could rest; therefore, the more timber and the more interstices along the roadway, the more dust would exist. It was probably due to the evenness of the roof and sides and the small amount of timber that only ¼ inch of dust was deposited; the interstices were full and could not receive more. Mr. Fowler commented upon the quantity of dust being so small, and Mr. Jackson's remarks partly gave the explanation. Mr. Fowler is working the top hard coal-seam, and if he had in years gone by planted the coal there himself, made the roof and seam and all the surroundings, it was doubtful whether he would have wished it much different from what it was. But there were many present that day who would have made the seams they have to work very different from what they found them, if they could have controlled the planting of the coal-beds. The top hard coal-seam could scarcely be compared with the black-shale and other seams, which were so dusty and composed of friable coal. With regard to the three points named by Mr. Fowler—viz., close-ended waggons, emptying waggons at the pit-top, and haulage by machinery—he might point out that two of these conditions were complied with at the Blackwell colliery at the time of the explosion. The iron tubs he had seen in South Wales were close-ended, and not in a cage-form, yet these mines were very dusty. Mr. Fowler intimated that he would sweep the roadways—the sides and the roof, he presumed. If the roadways were swept, what would become of the dust? It would be carried by the ventilation and be deposited elsewhere. It might pass round the faces and up the upcast if it had a short distance to travel. No mention appears to have been made as to the thickness of dust on the floor of the roadways; perhaps, if Mr. Fowler had estimated the thickness and quality, he would give the result. But what was the object of all the precautionary measures with respect to coal-dust on the roadways? If it be for the prevention of a coal-dust explosion, then he advised them to go to the root of the matter.

What was the cause of explosions? To begin with, it must be a light of some sort. If it were gas ignited by a naked light, let them take naked lights altogether out of the mine and increase the ventilation. If it were blasting, let them, if possible, take their explosives away from the roadways altogether. There was no doubt that the question of dust would have to be considered, and it was obvious that the use of gunpowder on dry haulage-roads was dangerous and should be prohibited. With respect to watering, he did not quite agree with Mr. Fowler as to the health of the workmen being affected. In some of the best watered collieries in South Wales the atmosphere of the main roads appeared to be saturated with moisture, and the current of air when it arrived at the working-face was clear and free from dust. That was where water-sprays were used, but it was not a cure for the dust. The dust was so fine that, if the current of ventilation was saturated with moisture, it appeared to form a film of wet dust which protected the fine dust underneath, and which, if disturbed, became a cloud of dust. Water-spraying was not a cure for the dust question; it was a material help, but other remedial measures should accompany it.

Mr. T. A. SOUTHERN (Derby) thought that Mr. Fowler's paper dealt with a very important subject and treated it in a very practical way. He remarked that the general custom in South Wales was to use open lattice-work trams, these trams stand about 3 feet high above the rails, and the coal was built up in large blocks to 4 or 5 feet high; very great facilities were afforded for dust being raised in a cloud from the loaded trams on their way to the shaft; and small coal fell on the floor, which being trampled upon and ground into dust, and kicked up by men and horses passing in and out, became deposited upon the timbers. Mr. Fowler suggested that they should take a middle course between the dry method and the wet method, and he agreed with that view. He (Mr. Southern) had often thought when this subject had been discussed that they heard a great deal too much about watering and too little about the removal or the prevention of the formation of dust. A great deal of expense must be incurred in watering the same accumulations of the dust day after day, and he had several times urged that more attention should be attached to dust-removals; he thought that in future the members should still more strongly advocate the prevention of the formation and accumulation of the dust. He could quite agree with Mr. Fowler's remarks as to the enormous quantity of water that would be required to thoroughly saturate any large mine, because in a previous discussion on the subject he had pointed out by calculation that under certain conditions, with a large

mine, the drying power or absorptivity of a large ventilation, owing to the rise of temperature, might amount to even as much as 160 tons of water in 24 hours in winter time. Mr. Fowler mentioned that the quantity of dust found in Cinder Hill colliery amounted to 1½ cubic feet of dust per lineal yard of road. It had been stated by Mr. Galloway some time ago that 1 lb. of dust in 160 feet of air, or 1 lb. of dust in 1 lineal yard of a road of average dimensions was sufficient to form an explosive atmosphere with a small percentage of gas. Consequently, 1½ cubic feet of dust would give very much more than this needful supply to form an explosive atmosphere. Mr. Fowler mentioned that the maximum thickness of the dust in one case did not exceed 1 inch. In some of the steam coal-seams of South Wales the dust may be seen much more than 1 inch thick in all sheltered, undisturbed places along the main roads. He certainly thought that a great deal depended upon the character of the coal in the seam, some seams yielding a great deal of fine dust from smutty partings of the joints or slips in the coal, and he did not think that they should make too much of comparing one seam or one colliery with another, but simply give due attention to what could be done to minimize the source of dust in all mines alike. Naturally, those who had large collieries, where open-ended tubs or lattice-frame trams were in use, would be prejudiced against Mr. Fowler's condemnation of these open tubs and trams, and they would be disinclined to agree to anything which would involve a heavy expenditure in abolishing or rebuilding them; but such a change would undoubtedly contribute to the prevention of dust. It was quite possible, in some collieries, after the ground had settled, to make the surface of the sides and roof smooth, as described; and in such cases an outlay of 10d. per foot, or £220 per mile, for this purpose would prove a good investment, by obviating or minimizing the cost of watering. In many collieries, unfortunately, the ground was never quite settled, and to maintain smooth surfaces would be quite impossible. He thought, however, that in all collieries, in the laying out of roadways in future, a good deal could be done in designing the timbering, and so forth, so as to keep the surfaces, at any rate, much smoother, if it were kept in view that this was desirable. He would suggest that a summary of the best precautions against the formation and accumulation of coal-dust would be:—close-sided tubs and trams; revolving-tipplers; the tops of the loaded tubs should be sprinkled before starting outbye, especially where main-and-tail rope haulage at high speeds was in use; regular cleaning of the floor; making roadways with as smooth surfaces as possible, by plastering sides or arching under bad

roof; occasional sweeping of the roof and sides, and where possible—and in some mines it was possible—it was a very good plan to have the travelling road for men and horses not on the main haulage-roads, but in a duplicate intake airway, or in the return-airway, so that any lumps of coal falling off the trams might not be so greatly crushed. It certainly appeared desirable that the use of gunpowder should be entirely prohibited in all main haulage-roads unless the roof and sides were absolutely wet; and in this prohibition he would extend the definition of a main haulage-road, so as to include every road along which the coal was hauled from several stalls, whether by horses or otherwise.

Mr. GEORGE LEWIS said that the thanks of the members were due to Mr. Fowler for having introduced the subject of coal-dust at a time when they were all more or less revolving in their minds the best means of dealing with this question. The members might not all agree with Mr. Fowler in the deductions that he had drawn, but he thought that if those and a few others of a similar nature were carried out, no matter what the expense might be, it would to a great extent relieve mines of the uncertainty of these dust explosions. Utopia was a very pleasant place no doubt, but at times there was a difficulty in getting there, and this paper only further demonstrated the great difficulty of the dust question. There was no doubt that Mr. Fowler had a mine that was being worked under very favourable circumstances, and if he was able to do so, and did so construct his roads as to give them a model of what roads ought to be or might be, he was sure that the members would be exceedingly glad to make an inspection, and do what they could in mines under their charge. He was afraid that many colliery owners would object to the suggestion that all tubs with open ends should be blocked, and the produce of many seams could not be loaded into the tubs unless the tubs themselves had open ends. He thought with Mr. Fowler that there was much that could be done, and would have to be done, in the main roadways of collieries with regard to the removal of dust. There was a good deal that the members might and could do without compulsion, and ought to be able to do with regard to their main roads. He very much questioned whether coal-dust could be altogether avoided, even under the circumstances which Mr. Fowler had pointed out. There would always be dusty roads in a mine, but what the definition of a dusty mine would be he must leave to the future. He thought that the thanks of the members were due to Mr. Fowler for initiating a discussion of this kind at a time when they were all more or less

trying to solve the question. He moved a vote of thanks to Mr. Fowler for his paper, and that the further discussion be adjourned to another meeting.

The motion was approved.

Mr. FOWLER thanked the various speakers for their criticisms, and suggested that his paper be read and read again, as in many cases it answered difficulties which might occur on first perusal. Thus, Mr. Stokes pointed out that dust may be dry under water-spray; and seemed then to suffer from a fit of hopelessness, and found comfort only in high explosives. His (Mr. Fowler's) desire was to knock the bottom out of the aquatic treatment, and he maintained that nothing said in the discussion had re-established it. It was very easy to say that one coal was softer than another and that conditions varied, but supposing that the Cinder Hill coal had been three times as soft, would the arguments for his (Mr. Fowler's) position have been in the least degree weakened? The fact of the matter was that up-to-date mining engineers had first discredited dust, and had next taken fright at it, and considered only violent and costly remedies. He (Mr. Fowler) merely asked: How little dust can we make? How can we most easily remove it? And his paper was intended to answer these questions.

The following paper by Mr. W. S. Gresley on "The Yorkshire and Nottinghamshire Coal-field," etc., was taken as read :—

THE YORKSHIRE AND NOTTINGHAMSHIRE COAL-FIELD: GEOLOGICAL SUGGESTIONS RELATIVE TO ITS EASTWARD EXTENSION BENEATH THE PERMIAN AND SECONDARY STRATA INTO LINCOLNSHIRE.

By W. S. GRESLEY, F.G.S.

Mining engineers and royalty-owners more or less interested in the future extent of the productive coal-field of South Yorkshire, Derbyshire, and Nottinghamshire, as obscured by Secondary rocks, have (the writer thinks) hitherto scarcely taken a broad enough view of the question, in order to reach any general or uniform conclusion. He has thus been led to make an attempt with (it must be acknowledged) the very imperfect materials at his command (this paper is written on the shore of Lake Erie, U.S.A.) to supply a few perhaps somewhat original ideas and suggestions with the view of trying to solve the problem. These ideas or methods of testing the matter may be arranged thus:—

1.—The size of the coal-field, indicated by the general trend of the strata.

2.—The area of the coal-field, suggested by the sizes of others.

3.—The extent of the coal-field, based on the theory of the origin of mountains.

4.—The limit of the coal-field, fixed by the re-elevation theory.

5.—Stratigraphical considerations affecting the question.

6.—Selection of sites for trial-borings.

There are but few exposures of the pre-Carboniferous rocks in Great Britain, except in the western and north-western parts.

(1) We are all aware that the Coal-measures are chiefly confined to the central area, while the Secondary and later series occupy the eastern and south-eastern parts of England; in other words, that the general strike of the strata is north-eastern and south-western, while the prevailing dip is towards the east or south-east. This general eastwardly dip ought to show a corresponding dip in the coal-fields, notwithstanding their basin-shapes, and the writer thinks that the majority of the British coal-fields do possess a decided tendency towards deepening as followed towards

the east. The prospect also of discovering new or entirely concealed coal-fields is almost wholly confined to the south-eastern counties of England,* so that the inference to be drawn from the foregoing is that the concealed Midland coal-field does or did originally extend to the east for a long distance.

(2) In a section from Perthshire on the north-west to, say, Darlington, it first crosses the eastern end of the exposed coal-fields of the Clyde and Forth, which is about 25 miles wide; and coming to the Great Northern coal-field, we find it to be some 40 miles across from north to south. Now, the inference is that the next coal-basin on the same line would be still wider, nearly double the width; and so it is, for the section strikes across the Midland coal-field, measuring some 70 miles from north to south.

Next, in a section across the country from west to east, crossing the great central plain of Ireland, there are two or three widely-separated but quite diminutive coal-fields. In North Wales, there is the little coal-field of Anglesea, say, 4 miles wide only; then, after an interval, a larger coal-field, that of west Flintshire; another barren stretch and the section strikes the North Wales coal-field, which possibly reaches into Cheshire. The very much larger Cheshire-Lancashire coal-region comes next, with a width from west to east of some 35 miles. Again, the natural supposition is that if another and more easterly coal-field exist, it may be expected to be yet wider than the last; and so it probably is, for the maps in the *Report of the Coal Commission* give about 45 miles as the probable breadth of the workable area of coal-beds in the Yorkshire, Derbyshire, Nottinghamshire, and Lincolnshire region (the great Midland coal-field).

Then let a similar section be run from south-west to the same terminal region Dr. Edward Hull marks on his map† a possible coal-field of, say, 8 miles wide south of the Mendip hills in Somersetshire; next, there is the Bristol and Somerset coal-field about 22 miles wide; and, following a longish barren interval, the coal-region of South Staffordshire, Warwickshire, Leicestershire, and South Derbyshire (to be considered geologically as one) is found with a width of about 35 miles. Then, again, the natural inference points to a yet wider coal-field, if one exists, still further to the north, and sure enough there it is—the Midland, with a width of, say, 50 miles on the line of this section. Thus it becomes

* The finding of coal in Oxfordshire and in Kent, since the publication of the *Report of the Coal Commission* in 1870, confirms this opinion.

† *Coal-fields of Great Britain.*

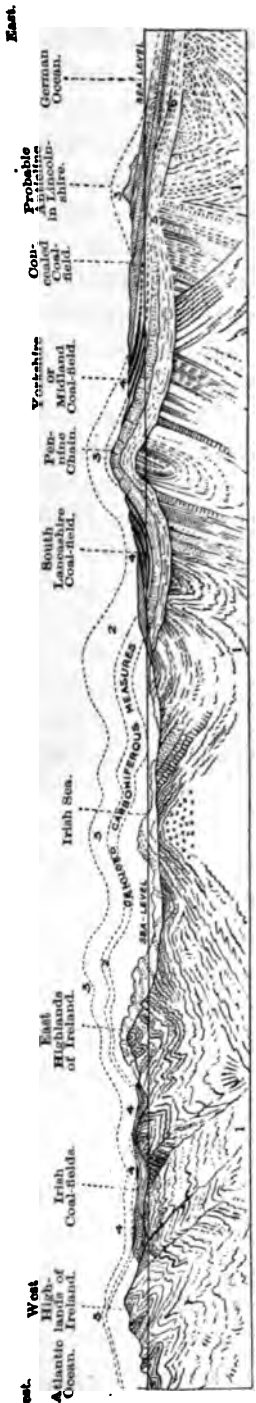
interesting to notice that the tendency of British coal-fields is to expand in an eastwardly course, or exactly in accordance with the broad features of the physical stratigraphy previously mentioned.

(3) Since the sizes of coal-basins are mainly governed by the ridges or anticlines which separate or divide them one from another, it becomes important, if we would predict the size of a concealed coal-field, to look to the origin, dimensions, and topography of these anticlines; in short, to locate, as far as possible, hidden or buried ridges beneath rocks deposited at a later period and practically having no stratigraphical relationship to the Carboniferous series. The writer believes it is becoming more and more a recognized fact that mountainous regions are principally confined to those in which the thickest vertical piles of sedimentary strata have been accumulated. Mountain-chains are characterized by more or less complicated, folded, squeezed, faulted, and altered masses of strata in various stages of removal by erosion; and it has been remarked that "mountains come to an end where the rocks thin out." Now, where the strata were deposited of greater thickness, the inference is that the coast-line of the land-area furnishing the sediments, was not far off (and receded as the area of deposition advanced, or as the strata became thicker). It must also be clear, that in proximity to the source of the sediments, or where the deposited materials are thickest, there the strata would be coarsest; and as accumulation and subsidence must come to an end somewhere, sometime, it is probable that in the case of the Coal-measures, it ended with the completion of them, or with the Permian.

But what was the cause of the emergence or upheaval that followed? In answer to this question, the writer is inclined to the opinion of those who have suggested that the internal heat of the earth acted upon the deeply-subsided very thick pile of strata and produced a softening of the rocks, accompanied by a weakening and possibly some swelling of the strata. Now, weakening implies yielding, and it seems probable that the only way the rocks could give way or obtain relief would be vertically upwards; and once elevation began, erosion would also ensue, and so the tendency would be in the direction of prolonged elevation or the production of mountains; such uprising continuing until equilibrium was restored over the region affected. Following out this line of reasoning, accompanied by the application of observed facts in typical, elevated and crumpled areas—*e.g.*, the Alleghany mountains in Pennsylvania, etc.—it may be observed that these enormous regional upthrusts of strata produced series of roughly parallel ridges or anticlines

and synclines along the strike of the main axis of elevation, and that the ridges or waves are found to fall away in vertical height and increase in breadth as followed away from the mountain-chain. It is to these kinds of strata-waves that the coal-basins primarily owe their shapes; and as the question now under discussion has reference to the eastwardly extension of the Midland coal-basin—for a "basin" it is almost certain to prove to be—it is with the anticlines trending approximately north and south that we have to deal. How far to the east, then, of the so-far explored coal-field is the next anticline of importance likely to be found? Will a study of the principal north-and-south ridges and their accompanying synclines, as traced across the country from west to east, afford a clue to the location of any of these anticlinal ridges which may now lie buried beneath the Secondary rocks of Nottinghamshire and Lincolnshire? From a personal knowledge of the region, and from a study of geological maps and sections, the writer is inclined to think that a practical result can be reached in answer to this question.

Beginning with Scotland and Ireland, there is good evidence of what were originally rudely parallel strata-folds of vast proportions stretching about north and south from one end of what is now Great Britain to the other; and examining what remains of these great crushed and plicated strata or earth-crust waves, as we come east, they are observed to grow less marked, both as regards structural geology, and their topography. Now, the writer regards the Pennine chain or "back-bone of England" as only a comparatively small anticline, and in reality to be one of the diminishing strata-waves connected with the general north-and-south systems of upthrust foldings following the close of the Primary epoch. What the writer conceives to have been pretty much the actual state of affairs, geologically and physically, during the Primary-Secondary interval across this line of the then continental area, is shown in the diagram (Fig. 1). The dotted wavy lines are intended for the original stretch of Coal-measures (entirely across Great Britain) after the general pre-Triassic upheaval had taken place, and whilst enormous denudations of the coal-series were operating. If, then, the actual facts are in general accord with this idea and with the diagram, then the crest of the supposed anticline next east of the Pennine axis ought to be found at a greater distance from that axis than that axis is east of the next great ridge of rocks west of it. Where this latter ridge was, we are left to conjecture, because the Irish Sea now probably covers its remnants or "bones;" but the character of the strata in North Wales, the Isle of Man, etc., coupled with the rising to the west of the Lancashire Coal-measures



under the Red rocks, seems to point to an axis of large dimensions where it has been marked on the section.

In this kind of an enquiry it might possibly be useful, supposing sufficient reliable data could be procured for the purpose, from a more careful investigation of the structural geology of the region in question, to apply a mathematical test of the theory of strata-waves, in order to see whereabouts to the east of the known coal-field an important anticline might be expected to put in its appearance.

And bearing upon this future-anticline problem, may be mentioned the fact, that the observed dips of strata composing typical series of upheaval-formed anticlines and synclines, would seem to warrant the belief that the easterly dips in these coal-fields would be found steeper than the westerly ones; in other words, the steepest dips of parallel series of anticlines, face away from centres or lines of maximum disturbance: if this phenomenon holds good in the Midland coal-basin, the coal-beds are likely to rise more slowly, when the supposed (say Lincolnshire) anticline on the east is approached, than they dipped away from the Pennine chain. But had we no better geological data, to mark out or point to any particular locality where the Coal-measures are likely to crop up

Fig. 1.—Longitudinal Section, from West to East, through Ireland, the Irish Sea, and England, showing:—

1. The imaginary pre-Carboniferous Floor of the Coal-measures (after the Upheaval of the latter).
2. The probable original Thickness of the Carboniferous Series, when they were upheaved (dotted and full lines, etc.).
3. When the Coal-measures had been thrust into approximate north-and-south Folds, and subjected to Denudation.
4. The proved Coal-fields (of Ireland, Lancashire-Cheshire, and Yorkshire, etc.).
5. The probable Position and general Character of a concealed Anticlinal Axis in the Coal-measures beneath Lincolnshire
6. The supposed gradual thinning-out of the Carboniferous measures towards the German Ocean.

Horizontal Scale, about 60 Miles to 1 Inch.

against the Secondary rocks to the east of the present most easterly Midland coal-field collieries, it would be little better than mere guess-work.

(4) The writer is, however, of opinion that we are not left so entirely in the dark on this point as some may suppose. French geologists of note have recently shown, in a more or less demonstrable way, the opinion held by Mr. Godwin-Austen, that anticlines existing in the Secondary rocks approximately coincide with the ancient anticlines in the Primary series. The meaning of this is, that lines of ancient upheaval were lines of weakness in the earth-crust, and when subsequently (in post-Secondary times) there was a tendency to get relief, for strains among rocks to seek an equilibrium, it was natural that former lines of weakness should again yield and a further uprising ensue. Now, unless the writer is mistaken, the outcropping Lias and Oolite from Market Weighton in Yorkshire to some few miles east of Lincoln show a decided easterly dip, whereas the Trias and Permian spread out to the west of that line with comparatively little easterly dip. The longitudinal section No. 2 upon Sir A. Ramsay's geological map of England and Wales,* shows a decided ridging-up of the Secondary rocks in the neighbourhood of Horncastle. Thus there appear grounds for supposing that a buried anticline in the Coal-measures (if they extend thus far east) exists from this part of Lincolnshire northward into Yorkshire, passing, say, a little west of Hull. So that whether we consider the question of this probable eastern barrier to the Midland coal-field from the origin-of-mountains standpoint or that of post-Secondary re-elevation, an underground north-and-south ridge in the Primary rocks is suggested.

(5) One or two petrological observations may be deemed in order in this connexion. Dr. Hull long ago showed that the general thinning-out of the Coal-measures in central England towards the east, implied that the source of the sediments composing these rocks was in the west. A perusal of vertical sections in the South Lancashire and Midland coal-fields indicates a general thickening of the arenaceous beds as followed west. Published *Sections in West Yorkshire*, by Messrs. Davis and Lees in 1878, show a decided attenuation of the sandstones of the Carboniferous as traced eastward; so that, unless recent pit-sinkings, along the basset edge of the Permian, reveal no appreciable eastwardly thinning of the Coal-measures, and if no strata of limestone set in towards the same direction, in order to, as it were, compensate for any corresponding tailing-out of the sediments; then, a gradual thinning away of the Coal-measures may

* Fourth edition, 1877.

be expected in the direction of the German ocean.* The beds of coal are always the most persistent strata in the series, so in this field they are likely to hold on as far as the shales and fireclays extend. Whether the thickness and quality of the coal-seams will also be obtained, is, in the writer's estimation, more than doubtful. He views this part of the question from two standpoints, namely, (*a*) that of the origin of the coal-beds, and (*b*) the cause of debitumenization of coal.

The writer has recently ventured upon some views on these two subjects,† therefore it seems necessary here to say, that as the British coal-forests or jungle coal-growths probably had their origin, or grew out from, as occasion offered, the same continental land area as that which furnished the associated strata, the "Atlantis" of Sir J. W. Dawson, it is only reasonable to suppose that such growths would, each time they crept seawards, never accumulate so great a thickness of vegetable *débris* as was produced nearer shore. As to the quality of the coal, it seems to the writer that the more coal-beds are associated with arenaceous rocks, and come within the influence of regions composed of anticlinal and synclinal folds, the more debitumenized or the better their quality becomes. Again, we may point to our type of coal-field, that of Pennsylvania, as useful for reference in this connexion. It is proper to point out that coal under the sea off the coast of Durham not only gets much flatter but deteriorates somewhat in quality. The top hard coal-seam in Derbyshire diminishes in thickness towards the east. The writer thinks that the general character of the Lancashire coal-seams is better than the general run of those of the Midland coal-basin, and the average quality of the coal of the two Staffordshire coal-basins is generally admitted to be rather superior to that of the seams of the coal-fields further to the east. The South Wales coal-seams also are superior to those of the Forest of Dean and Bristol-Somerset-basin. We should also remember the almost phenomenal coming-together of the coal-beds of the Cannock district in the vicinity of Dudley where we get the great ten-yards coal-seam; but a repetition of this occurrence in the eastwardly attenuation of the Midland and Yorkshire coal-field must not be counted on.

(6) Were the writer to attempt to draw a practical conclusion from the foregoing remarks as to the probable extent of the concealed coal-field, or where coal is not likely to be found east of the known area

* In the typical coal-field of Pennsylvania, as the siliceous strata dwindle westwardly, calcareous deposits put in and increase in that course.

† "Formation of Coal-seams" and "Origin of Anthracite," *Proceedings of the Geological Society, London*, 1894, vol. xlix., page 11.

of it, he would (in the absence of more definite geological data) suggest that when the time comes for prospecting the Lincolnshire district, boreholes put down, say, 10 miles to the east-north-east of Lincoln, and about the same distance to the north-east of Horncastle, would be not unlikely (if deep enough) to strike productive Coal-measures, avoiding the supposed anticline lying between them; at any rate, if one of these two trial-holes missed the Coal-measures the other might find them. This implies that the writer sees no good reason why Coal-measures should not exist all the way from the outcrop of the Permian eastwardly to the sea, with the exception of a barren area to be found somewhere under part of Lincolnshire, caused by a pre-Triassic upheaval, which was followed by the erosion of the Coal-measures before the Secondary rocks were deposited. The writer's object has, however, been rather that of suggesting what he believes are somewhat novel ways of treating the subject than of reaching conclusions or locating limits. This communication will not, however, have been altogether unproductive, even if the outcome of it amounts to nothing more than a criticism of the writer's method of handling the subject.

Mr. G. H. KINAHAN (late District Surveyor on H.M. Geological Survey, Manchester) wrote that he would not presume to give an opinion on the English coal-fields, but as Mr. Gresley had brought in Ireland it might be allowable to state the facts in connexion with its coal-fields and the associated Carboniferous accumulations, more especially as Mr. Gresley's section (Fig. 1) does not agree with what, in his opinion, had taken place.

During the time of the Carboniferous sea Ireland was an archipelago, while around and against these islands of pre-Carboniferous rocks the newer formation accumulated. This statement is self-evident, as on the northern side of these protrudes where there was deep water, we find deep-water limestones, while on the other sides we find littoral accumulations on the same geological horizon. These occurrences have been explained by a diagram in the *Manual of the Geology of Ireland.**

* Page 65.

The area of the Carboniferous rocks of Ireland may be divided into two groups, one south and the other north of the valley running from Galway to Dublin. South of this line, the Coal-measure areas are defined, as there are no newer accumulations on them. To the eastward, there is the greatest thickness of workable coal-seams, while westward, in Limerick and Clare, the thickness of the Coal-measures is excessive, while the seams of coal are so thin and impure as to be valueless.

North of the line, in the Connaught coal-field, the measures take a new feature, as the coal-seams occur, not in the Upper Coal-measures, as in Leinster, but in the Middle Coal-measures. The coal-seams are fairly good, although thin, while the associated country-rock has much of a marine aspect, as if the rocks had been deposited in the sea or brackish water. Here also, as in Leinster, the coal-seams appear to thicken to the eastward, but that part of the field has been very little explored.*

The principal, or what ought to be the principal, coal-field of Ireland occurs in the county of Tyrone and province of Ulster. Here the coal-seams are very aggravating, as they chiefly seem to have accumulated in small detached areas, each of which had an independent system; and then, to complicate matters, prior to the Permian age the Coal-measures were subjected to violent upthrusting from the south-east, that pushed the coal-seams on to other portions of the same seams of coal, so that now there appear to be many more distinct coals than is really the case. This area has been divided up into the Drumglass or Dungannon colliery, the Annagher colliery, the Coal-island colliery, and the Annaghone colliery.

In the Drumglass colliery, there are two coal-seams that evidently are the representatives of the main coal-seams of the Connaught coal-field; and here, as there, they occur in the Middle Coal-measures. Here they have considerably increased in thickness and importance, and there does not appear any reason why they should not extend under the Coal-island coal-field, also southward and northward under the newer Trias rocks.

The Annagher, Coal-island, and Annaghone collieries occur evidently all in Upper Coal-measures, but although so near together, no one has been able to correlate one set of coal-seams in one colliery with those in the others. This appears to the writer to be due to the coal-seams in the different sections being repeated by upthrusting from the south-east. In the Annagher colliery, the coal-seams seem to lie more regularly than in Coal-island and Annaghone. In Coal-island, the coal-seams are all heaved up and down by faults, and seem also to be inverted, or

* "Economic Geology of Ireland." *Proceedings of the Royal Geological Society, Ireland*, new series, vol. viii., page 71.

one part of a coal-seam has been upthrust on to another portion. In the Annaghone colliery, the inversion is most conspicuous, as the main coal-seam, bottom upwards, lies on itself. Here there has been considerable faulting, as to the northward the Coal-measures are brought down by a fault against the Lower Limestone, while to the southward there is another fault that brings down the Triassic rocks against them. It is evident that the Carboniferous rocks were considerably disturbed and denuded prior to the accumulation of the Trias and Tertiary rocks. Still, there is no reason why Coal-measures with profitable coal-seams may not extend under the adjoining Trias and newer rocks into the counties of Derry and Antrim.

In north-eastern Ireland, northward of a ridge of the older rocks, the Coal-measures, as in the Edinburgh coal-field, are midway down in the Carboniferous. These measures are very instructive, as to the south-west in the county of Derry they are unprofitable shales and grits, while at Ballycastle, in county Antrim, they contain valuable coal-seams.*

It is evident that in Ireland, during the time of the accumulation of the Coal-measures, land-surfaces more often occurred, and of greater duration to the eastward than to the westward; also that the western rocks as shown by these fossils were in a great measure of marine accumulation, while the fossils of the eastern accumulation are more of fresh-water origin. Also, while the Leinster Coal-measures were accumulating, the granite hills must have been awash, as some of the massive grits are so much composed of granitic materials, that a hard specimen at first sight might be mistaken for a granite. One massive bed is especially granitoid, and forms a good horizon in both the Queen's County and Tipperary coal-fields.

In Ulster, if we may judge from the sparse remains of the Trias, Lias, and Cretaceous, these different groups had their maximum accumulation towards the eastward, while they rapidly thinned westward. Of the Tertiary rocks very little can be said. There seem to have been Eocene and Miocene periods of great vulcanicity, with a long rest between, represented by the iron-ore measures. The lignite in the latter ought to account for at least an interlude of 2,000 or 3,000 years. In these accumulations, as in the Coal-measures, the land-surfaces seem to occur and to have been of longer duration to the eastward. The successive flows of lava also seem to have been greatest to the eastward; this, however, is a mere speculation, as on account of the excessive denudation

* *Manual of the Geology of Ireland*, page 68.

of the Tertiary rocks nothing of weight can be said about them. The Pliocene may or may not be represented, as the Lough Neagh beds in the counties of Tyrone and Antrim, the pipe-clays of Cahir, in county Tipperary, and of Roscrea, King's County, and the blue marls of Wexford, may possibly be of Pliocene age, but they are of such a fragmentary character, that they are scarcely worth mentioning, as we can learn nothing from them.

The CHAIRMAN suggested that the discussion of Mr. Gresley's paper and of Prof. Hull's paper on "The Eastern Limits of the Midland Coal-fields"* might be taken together. When Prof. Hull read his paper, he (the Chairman) objected to Derbyshire and Nottinghamshire being excluded from the "Midland coal-field," of which up to that time he had believed them to form part. Prof. Hull seemed to think that that was not so, and declined to acknowledge them as such, but suggested that they should be called the North Midland coal-field. He (Mr. G. Lewis) believed the coal-field of Nottinghamshire and Derbyshire to be a part, if only a small part, of the Midland coal-field. Mr. Gresley's paper appeared to him to be a very useful one, and the theory which the writer tried to establish might be the correct one. The theory, as they knew, was that the coal-fields of this country lie in troughs and waves of the strata; the last wave was westward of the Erewash valley district, and the next north-and-south wave might possibly be approached somewhere in a line to the west of Hull. If this were so, it would to a very great extent allow—a theory, which they had been trying to establish for some years—of a very considerable easterly extension of the Midland coal-field. There was no proof to the contrary as far as he knew, and he was strongly of opinion, and had been for many years past, that the Midland coal-field extended to the German Ocean. This seemed to be the idea of Mr. Gresley, and although he now was living in Pennsylvania, most of the members would recollect that he had had considerable experience in the Midland district, particularly in connexion with the late Mr. J. T. Woodhouse, a member of the Royal Coal Commission of 1866 and subsequent years. He was very glad to read his theory, because to a great extent it showed ground for the opinion that had long been held and expressed by himself and many others in the Midland counties, and ran somewhat on the same lines.

Mr. G. E. COKE (Nottingham) considered that Mr. Gresley's paper was a very valuable one. He did not profess to be competent to give an opinion as to the geological theories, but with regard to some of the

* *Trans. Fed. Inst.*, vol. xi., page 9.

writer's conclusions he fully agreed. A borehole at Ruddington with which he was connected would probably confirm Prof. Hull's theory that the anticlinal fault-barrier ran out the Coal-measures to the south of Nottingham.

Mr. H. E. Hewitt (Derby) said that the two papers appeared to be a recapitulation of the opinions generally held by mining engineers as to the probable eastward extension of the Midland coal-field. It had scarcely been hoped that productive Coal-measures would be found in Norfolk and Suffolk, as all the evidence seemed to point against this probability, and was now strengthened by the results of the trial borehole, and by the opinion of Prof. Hull. It appeared to be highly improbable that even a small coal-field would be found in these counties, notwithstanding the fact that Coal-measures had been found at Harwich. One great feature mentioned by Prof. Hull was the Silurian ridge or bank which appeared to traverse the country. This bank probably cut off the coal-field towards Norfolk, but it was improbable that it divided the South Staffordshire coal-field from that of Warwickshire. It was yearly becoming more and more certainly a fact that these coal-fields join each other, or if the Silurian ridge does exist it must be very narrow, and probably is not elevated sufficiently to interfere with the continuity of the Staffordshire thick coal-seam which undoubtedly forms the rider, ell, two-yards, and slate coal-seams of Warwickshire. At Wyken, near Coventry, they are all practically one seam, being only divided by a few feet of strata, and in some cases by a few inches of shale or fireclay.

Mr. Gresley's arguments with regard to the extension of the Midland coal-field proper towards the east were sound, and were partially confirmed by a borehole recently put down about 10 miles east of Doncaster, and by another made about 12 miles south-east of Nottingham: in both cases productive Coal-measures were reached, although at a somewhat considerable depth. The workings of Linby and Newstead collieries extended for some considerable distance eastwards, and the coal-seams did not, he thought, thin out in that direction. It was possible that the anticline mentioned by Mr. Gresley might cut out the Coal-measures for some distance, but knowing that the bottom folds of an anticline are much flatter than the apex, that the measures dip towards the east, and that the productive Coal-measures, proved by the boreholes above-mentioned, lie at a considerable depth, it appeared probable that the anticline would not interfere with the continuity of the Carboniferous formation, and he thought that the arguments advanced by Mr. Gresley strengthen this view.

Mr. W. S. GRESLEY, in reply, thanked the members for the appreciation shown towards his paper. He regretted that the preparation of it, and especially, perhaps, that portion relating to the coal-fields of Ireland (touching the structures of which Mr. Kinahan had furnished interesting information), was undertaken without the ability to consult the latest geological reports on that very interesting little group of coal-fields, two or three of which he had visited about twelve years ago. For these reasons, as well as on account of the smallness of the scale on which the section is drawn, and consequent absence of detail thereon, Mr. Kinahan will perhaps overlook trifling inaccuracies. The section is only intended to set forth the salient features of the main groups of strata bearing upon the central idea in his paper.

The CHAIRMAN proposed a vote of thanks to Mr. Gresley for his paper.

The vote of thanks was agreed to.

DISCUSSION UPON MR. A. H. STOKES' PAPER ON "PHOTOMETRIC VALUES OF, AND NOTES UPON, VARIOUS ILLUMINANTS USED IN MINES."*

Mr. A. H. STOKES replying to Mr. de Grave's remarks, said that in order to prevent any error in the photometric test, three persons made independent observations and one of these gentlemen was the gas engineer of the works in which the tests were made; he was a skilled person as to the use of the photometer. There were small discrepancies, as pointed out by Mr. de Grave and others, but generally the results were fairly and relatively correct. The lamps were trimmed and the light registered by Mr. Hepplewhite, who endeavoured to fix the light at the maximum, and one person did the same work all through the experiments. There was one point he would like to note and that was the eyesight of persons. He was sure that his own eyesight was very good at a distance, but it required assisting when viewing near objects, and he did not know whether every person could detect a small cap of gas on the flame of a lamp. It seemed to him that the eyesight of the officials of mines might

* *Trans. Fed. Inst.*, vol. x., pages 135 and 499.

with advantage in some cases be tested just as with railway officials. But the three persons who made these tests had, he could assure the members, good eyesight, and were well accustomed to the work of testing and the use of lamps.

The discussion was closed.

DISCUSSION UPON MR. WILLIAM HAY'S PAPER ON "FENCING-GATES FOR WINDING-SHAFTS."*

The CHAIRMAN said that objections had been taken as to the working of these gates owing to the fact that if the cage was taken up beyond a certain point the shaft was left open. This was a very important point, and he did not see how in gates of that description it could be provided against. With any gate working automatically, he was afraid that the same thing would occur, and consequently the shaft would be left open in case the cage went above a certain height. He did not think that there was any practical difficulty in thoroughly informing the top banksman or the bottom banksman when the cage might leave the props, but he did not quite see how that affected the question of these gates. It seemed to him that it was a very desirable thing to provide against, because a man was only human after all, and an engineman sometimes might lift his cage 3, 4, or 5 feet above the landing-level of the pit. He might do it without injury to anyone, and he (Mr. G. Lewis) did not think that they could blame him very much unless it was a constant occurrence. It was their duty as mining engineers to provide against this danger, and perhaps some one had thought out a provision against it.

Mr. A. H. STOKES did not know if he had made himself clearly understood upon this question. Where two-decked cages were used for the purpose of raising and lowering workmen, there must only be one banksman in control, and the banksman in charge could not see his assistant. Supposing the head banksman was on the lower deck he should give all signals to the engineman, but he had to deal with the assistant on the upper deck. Now, how did the man on the lower deck know when the upper deck was loaded and ready to go away? How was he to act? By signal or by word-of-mouth? Both methods had

* *Trans. Fed. Inst.*, vol. x., page 480.

been tried, and that by word-of-mouth had signally failed. If the banksman on the lower deck had his deck of the cage loaded, and gave the signal to the engineman to go on before the upper deck was ready, a man who might be entering the cage would be caught. He was of opinion that the banksman in charge should be able to fence both decks before giving the signal to the engineman.

Mr. Watson, of New Hucknall collieries, had an apparatus in work which, so far as he could see, was very successful, and met all requirements. The banksman, before he gave the signal, fenced both entrances to the cage. All the workmen got off and on at one side, and there was no danger now in workmen riding on both decks, similar to the arrangement in operation at the Bestwood collieries. It was a question fast coming to the front—how to get the men safely into and out of the mine. It had been said that with twelve as a maximum, and riding all the workmen on one deck of the cage at large collieries, it would take an hour to get the men down. The fencing of pit-tops was worthy of discussion, and for this reason: many of the members were connected with large collieries where part of the workmen lived near the collieries, and there were 200 or 300 men coming to the mine in trains. If men living round the colliery got down before the workmen came in by train it would relieve the rush. But it was not so; they all came together, and hence the rush. He felt sure that Mr. Watson would be pleased to show his arrangement to any member who wished to see it.

Mr. W. HAY pointed out that the object he had in view when he designed the gates was to guard the workmen on the top deck of the ascending cage from attempting to alight on the bottom landing. He did not understand Mr. Watson's arrangement, but it seemed to him rather difficult for the bottom and principal banksman to close the top deck-fence without bringing it into collision with the men standing on the top deck. If an engineman made a practice of winding 3 and 4 feet above his landing when men were riding, he ought to be suspended.

Mr. C. SEBASTIAN SMITH (Shipley Collieries) desired to know how, in cases where automatic gates were closed by the banksman below, he was made aware that the men were all on the top deck.

Mr. STOKES said that the signal was given from the man on the bottom deck to the man on the top deck. There was no difficulty in the signalling.

Mr. C. S. SMITH.—And sometimes he thinks that he gets the signal.

Mr. G. E. Coke (Nottingham) thought that Mr. Hay had dealt with a different matter from that referred to by Mr. Stokes. Mr. Hay had been providing against men jumping off the top deck. As to any misunderstanding with the signalling, it seemed simple. The engineman ought not to move until he got a signal from both top and bottom banksmen.

The Chairman remarked, when they had to put 600 or 1,000 men down the pit, they wanted to do it very quickly, as Mr. Stokes said, otherwise the men became impatient. If they had to put workmen down quickly, every possible arrangement should be made for preventing accidents to them when going down.

The meeting was then closed.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE FIRTH COLLEGE, SHEFFIELD, APRIL 18TH, 1896.

MR. JOHN NEVIN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. GEORGE WHITE, Civil Engineer, Estate Offices, Mexborough.

Mr. EDWARD SOAR, Colliery Manager, Kiveton Park Colliery, Sheffield.

ASSOCIATE—

Mr. HERBERT FOULSTONE, Under-manager, Messrs. Needham Brothers & Brown, Borough Foundry, Barnsley.

STUDENTS—

Mr. WM. ROBLEY STEELE, Mining Student, Barrow Collieries, Barnsley.

Mr. ROBERT ROUTLEDGE, Jun., Mining Student, 2, Pilgrim Street, Murton Colliery, Sunderland.

DISCUSSION ON MR. G. BLAKE WALKER'S PAPER ON "THE ROTH METHOD OF FIRING SHOTS."*

Mr. L. T. O'SHEA, of Firth College, said that Mr. Geo. Blake Walker, author of the paper, had kindly obtained one of the Roth apparatus for the chemical method of exploding shots, and had asked him (Mr. O'Shea) to demonstrate the action of the different bodies which took part in igniting the detonator. One of the substances used in order to ignite the detonator was chlorine, a gas readily obtained when hydrochloric acid acted on manganese dioxide or permanganate of potash. Chlorine is an exceedingly active gas, and when brought in contact with certain substances they unite with the evolution of large quantities of

* *Trans. Fed. Inst.*, vol. x., page 95.

heat. One great objection to the use of chlorine was the disagreeable odour which it possessed. In Mr. Walker's paper it was stated that the substance on which the chlorine acted was antimony. This readily combined with chlorine and took fire when thrown into chlorine; but unless the chlorine was pure the chemical action took place without the particles taking fire. Another metal acted on by chlorine was copper, which also took fire in contact with this gas. Yet another body on which chlorine acted was mercuric oxide, producing chlorine monoxide, a very active and unstable gas, which often exploded in manufacture. So active was this gas that when sulphur, phosphorus, or similar bodies were brought in contact with it they took fire. Dr. Roth used a mixture of mercuric oxide and sulphur, which he called a priming mixture; this he placed on the top of the fulminate in the detonator, and then brought chlorine in contact with the mixture. The chlorine acted on the mercuric oxide, whilst the chlorine monoxide formed, acted on the sulphur, and great heat was evolved, which caused the explosion of the cap. The substances which Dr. Roth used to manufacture chlorine were permanganate of potash and hydrochloric acid.

The method Dr. Roth proposed for using the process in the pit was to have a small bottle in which are placed the permanganate of potash and hydrochloric acid. The permanganate of potash was placed in a capsule, the mouth of which was closed with oxide of zinc, so that the acid had to dissolve the zinc oxide before it could attack the permanganate of potash. He connected the bottle with a leaden tube of small diameter, which passed through a perforation in a cork, and inserted the open end of the tube into the cap, and then the cap was introduced into the cartridge. The tube could be of any length, and the apparatus could be placed at any distance from the shot-hole. When the cap had been placed in the shot, the stopper was placed in the bottle, and they awaited the action of the chlorine on the mixture, and the explosion of the fulminate.

So far as experiments went the mixture seemed to work very well, but performing experiments in the lecture-room and in the mine were very different. There might be objections to the method, but it seemed to him (Mr. O'Shea) to afford a very successful attempt to avoid the use of fuze in the mine. He (Mr. O'Shea) could not say that it possessed any great advantage over the electrical method, but there was the question of expense on which he was not justified in giving an opinion. One great practical objection appeared to him to be the danger of the leaden tube becoming closed; the bore of the tube was of small diameter, and in

stemming the shot a slight knock might cause the bore to be closed, and thus prevent the chlorine from reaching the detonator.

Another point he wished to remark upon, but with some diffidence, because the subject of it had only come to his notice that day. Mr. Walker was kind enough to get the mixture for him four months ago, and it was then perfectly yellow—just a mixture of oxide of mercury and sulphur. Now, however, its colour had changed to black, showing that a chemical change had taken place. Probably sulphide of mercury had been formed. If this mixture were put in the cap with the fulminate, and this chemical change took place, it would be a source of danger. What this chemical change was he could not say, as he had only discovered it that day, but if the mixture was not stable it seemed to him a serious objection to its use. However, it was a useful attempt to use a chemical method, and might lead to the adoption of some similar means in the future.

Mr. G. BLAKE WALKER said that he had nothing to add to what Mr. O'Shea had said, or what was contained in his paper. The only question was whether the arrangement was of such a kind as was likely to be of practical service in collieries. He moved a vote of thanks to Mr. O'Shea and the college authorities.

Mr. E. W. THIRKELL (Oaks Collieries) seconded the motion, and said that the experiments had been exceedingly interesting.

The resolution was carried unanimously.

Mr. O'SHEA, in reply, said that chlorine monoxide was a dangerous gas to make in any quantity. He did not want the members to imagine that there was any danger in the quantity made in the cartridge. It was perfectly harmless and safe used in the way suggested by Dr. Roth.

Mr. A. W. BENNETT (Leeds) asked whether it was proposed to use a length of leaden tube equal to that of the hole, depending on time for safety, or to carry the tube some distance, as in the case of electric wires? It seemed to him that the electrical method had several advantages over the Roth system. If the process depended on time for the chlorine to act on the permanganate of potash, he should like to ask whether there was not a chance of the chlorine getting at the permanganate prematurely owing to faults in the formation of the capsule, and if that was not an element of danger? On the other hand, if the leaden tube was to be as long as the electric wires the question of cost would ensue, and there would not be much advantage in this system over the electrical.

The PRESIDENT asked whether this system had been tried in England or Westphalia?

Mr. NASH (Clarke's Old Silkstone Colliery) asked whether there was any possibility of a shot not going off in a certain time, and how long the mixture in the bottle, or the effects of it remaining in the tube, would continue to act? Was there a possibility of the shot igniting when the man who was supposed to be attending to it was going to see whether the thing had gone off or not, and how a collier, who was not a chemist, was to know when the detonator had gone off?

Mr. G. B. WALKER said that very little more leaden tube was required than the length of the shot-hole. If the bottle was introduced just outside the shot-hole, it was all that was wanted. It took a couple of minutes for the chemical action to take place, and there was plenty of time for the man to retire. Dr. Roth wrote him that it had been used in Westphalia on a large scale, had been successful, and given satisfaction to those who used it; but no doubt the men employed would be specially skilled, would thoroughly understand what they were doing, and in such circumstances failures would not occur. There was no question of taking leaden tube to a great distance—he did not see any object to be gained by doing so. With regard to ascertaining whether chemical action had taken place or not, they would have to leave it for some hours, just as they left a missed shot in any case. After that they might assume there was no danger. He believed that the Roburite Explosive Company had obtained some of the apparatus, and they might lend them for experimental purposes.

The discussion was then closed.

DISCUSSION ON MR. H. ST. JOHN DURNFORD'S "NOTES ON THE SINKING OF THE NO. 1 PIT AT THE ACTON HALL COLLIERY," ETC.*

Mr. NASH said that Mr. Durnford promised information as the driving was advanced, to show what was the cause of the thinning-out of the silkstone coal-seam, and until they got that information the members could not proceed further with the discussion.

Mr. R. SUTCLIFFE (Barnsley) wrote that the geologist wishing to correlate the coal-seams of South Yorkshire with those of West Yorkshire could not do better than to visit the valley of the Dearne at Clayton

* *Trans. Fed. Inst.*, vol. x., page 444.

West and study the coal-seams with their intervening measures which crop out there. The coal-seams of South Yorkshire crop out on the southern slope of the valley, having a north-westerly rise, and they carry their names with them to the outcrop. The seams of West Yorkshire crop out on the northern slope of the same valley, rising to the south-west, bearing the West Yorkshire names to their outcrop. This fact brings the distinguishing names of the two districts very near to one another, and makes the identification quite simple and decisive.

It would appear that, at the time when the Geological Survey was made, the coal-seams of this neighbourhood were not much known, as we find on the geological map such names as "Clayton common coal" and "unknown coal," while at the present day these coal-seams are thoroughly identified—the former as the silkstone four feet, and the latter as the Thorncliffe thin coal-seam.

As may be seen from these remarks, the coal-seams south of Clayton West dip to the south-east, and those to the north dip to the north-east, forming an anticlinal ridge of easy inclination, which, together with the erosion caused in the formation of the valley somewhat north of the axis of the anticline, causes the lower measures with their coal-seams to crop out in this locality much farther to the east than otherwise they would have done.

There is an old impression, which he (Mr. Sutcliffe) believed still existed, that there is an east-and-west fault, which throws up the coal-seams to the south, but, in the writer's opinion, it will be found that no such fault exists, and that the difference of level is caused by the rise in the strata just referred to.

If, for convenience, the coal-seams below the Flockton bed, which seem to be common to both districts, are enumerated, the following results are obtained (numbering them downwards):—

No.	West Yorkshire.		South Yorkshire.	
	Name of Coal-seam.	Feet.	Name of Coal-seam.	Feet.
1	Old hards...	—	Parkgate	—
	Strata	120	Strata	120
2	Green Lane or Middleton little	—	Thorncliffe thin	—
	Strata	54 to 60	Strata	54 to 60
3	New hards or Middeton main	—	Swilly	—
	Strata	60	Strata	60
4	Wheatly lime or old men's	—	Silkstone four feet ...	—
	Strata	105to120	Strata	105to120
5	Blocking bed	—	Silkstone	—

All these coal-seams have been proved in the locality by actual workings. From this table it will be seen that the swilly coal-seam of the South Yorkshire district is the Middleton main coal-seam of West Yorkshire. The Middleton main coal-seam being the silkstone seam of West Yorkshire, it is clear also that it must be the swilly coal-seam of South Yorkshire.

Mr. JOHN NEVIN (Mirfield) wrote that the mistake in the identification of the Middleton main or West Yorkshire silkstone coal-seam seems to have arisen from the distance between the Haigh Moor and this seam being at Ackton Hall colliery less than usual, and this discrepancy seems to occur chiefly in the upper part of the section between the Haigh Moor and the Flockton coal-seams. He had drawn to scale the Ackton Hall section and one taken from two collieries in the West Yorkshire district (Fig. 2, Plate XII.). In the Ackton Hall section, the coal-seams at 1,455 and 1,458 feet appear to represent the Flockton thick coal-seam; the coal-seam at 1,495 feet, the Flockton thin coal-seam; those at 1,557 and 1,576 feet, the old hards coal-seam; the Green Lane or Middleton little coal-seam is absent; the coal-seam at 1,724 feet is the new hards, Middleton main, or West Yorkshire silkstone coal-seam; that at 1,808 feet, the Wheatley lime coal-seam; that at 1,932 feet, the blocking coal-seam; and that at 2,126 feet, the Beeston, or part of that coal-seam.

The seams between the Haigh Moor and Middleton main coal-seams vary a great deal in West Yorkshire. Commencing at the northern outcrop near Drighlington, there is found near the surface the blendings, or Flockton thick coal-seam, 2½ to 3 feet thick, generally containing a little cannel coal; 45 feet below there is the Adwalton black bed, or Flockton thin coal-seam, 2½ feet thick, and good house coal; and about 75 feet further, at 124 feet, the brown metal coal-seam, or the old hards, has the following section:—

	Ft.	Ins.
Coal	0	9
Dirt	0	5
Coal	1	1
Dirt	0	8
Coal	0	8
Dirt	0	5
Coal	1	0

To the south, at Gildersome, this coal-seam is found in two parts, as follows:—

	Ft. Ins.	Ft. Ins.
Coal	...	0 9
Dirt	...	0 1
Coal	0 11 to	1 3
Measures	15 0 to	21 0
Coal	...	0 6
Dirt	...	1 0
Coal	...	2 0

Further south, about Dewsbury, Thornhill, and Flockton, the first workable seam is the joan coal about 20 inches thick; about 80 feet lower is the Flockton thick or stone coal-seam, say 18 inches thick, part of it being good cannel; the Flockton thin coal-seam, good house coal, 2½ feet thick, is about 45 feet lower, or at 131 feet; then a coal, 15 inches thick, about 49 feet lower, or at 180 feet; the first old hards, good house coal, 2 feet thick, about 15 feet lower, or at 195 feet; the second old hards, 2 feet thick, about 15 feet lower, or at 210 feet. Only one of the old hards coal-seams is generally workable, but sometimes both are sufficiently near each other to be worked together. The Green Lane or Middleton little coal-seam, 28 inches thick, about 72 feet lower, or at 282 feet; the Middleton main new hards or West Yorkshire silkstone, 3 feet thick, about 66 feet lower, or at 348 feet. The Wheatley lime coal-seam and the blocking coal-seam, although not always workable, are always present.

The next seam or group of seams, the Beeston coal-seam, varies very much in thickness. Near Cleckheaton, a section is as follows:—

	Ft. Ins.	Thickness. Ft. Ins.	Depth from Surface. Feet.
Blocking coal-seam		2 6	90
Top Beeston coal-seam—			
Inferior cannel	0 10		
Good cannel	0 10		
Coal	0 2		
	——	1 10	280
Low Beeston coal-seam—			
Inferior cannel	0 4		
Dirts	0 7		
Good cannel	1 2		
	——	2 1	312
Low Moor, black bed coal-seam		2 9	540
Low Moor, better bed coal-seam		1 5	660

North of Batley, the Beeston coal-seams run as follows:—

	Ft. Ins.
Top bed, coal...	2 0
Soft bind, etc.	14 6
Coal	1 0
Dark bind, etc.	2 8
Low bed, coal...	2 0
Total	22 2

Near Morley, the Beeston coal-seams are found as follows:—

	Ft. Ins.	Ft. Ins.
Top bed, coal	2 2 to	2 6
Dark bind, etc.		14 0
Coal		1 6
Dark binds		2 6
Low bed, coal (with three partings) ...		3 6

East of Leeds, the Beeston forms one seam with 4 to 5 feet of clean coal.

At Liversedge, Dewsbury Moor, and Mirfield, all within 1½ miles of each other, the measures containing the Beeston coal-seams are as follows:—

Liversedge.			Dewsbury Moor.			Mirfield.		
	Thickness.	Depth.		Thickness.	Depth.		Thickness.	Depth.
	Ft Ins.	Feet.		Ft. Ins.	Feet.		Ft. Ins.	Feet.
Blocking coal-seam	2 6	—	Blocking coal-seam	2 0	—	Blocking coal-seam	1 8	—
Coal-seam ...	1 0	147	Coal	2 3	178	Coal, 11 ins. }		
Coal-seam ...	2 5	170	Cannel	0 9	190	Dirt, 3 ,, }	1 8	170
Coal-seam ...	1 6	186	Coal and dirt ...	1 11	213	Coal, 6 ,, }		
						Cannel	0 5	182
						Coal and dirt ...	1 11	219
						Coal	1 6	235
Low Moor, black bed coal-seam	2 7	432	Low Moor, black bed coal-seam	2 6	450	Low Moor, black bed coal-seam	2 6	474

These sections show that although the distance between the blocking coal-seam and Low Moor black bed coal-seam is fairly regular, the intervening group of coal-seams (representing the Beeston) is very irregular.

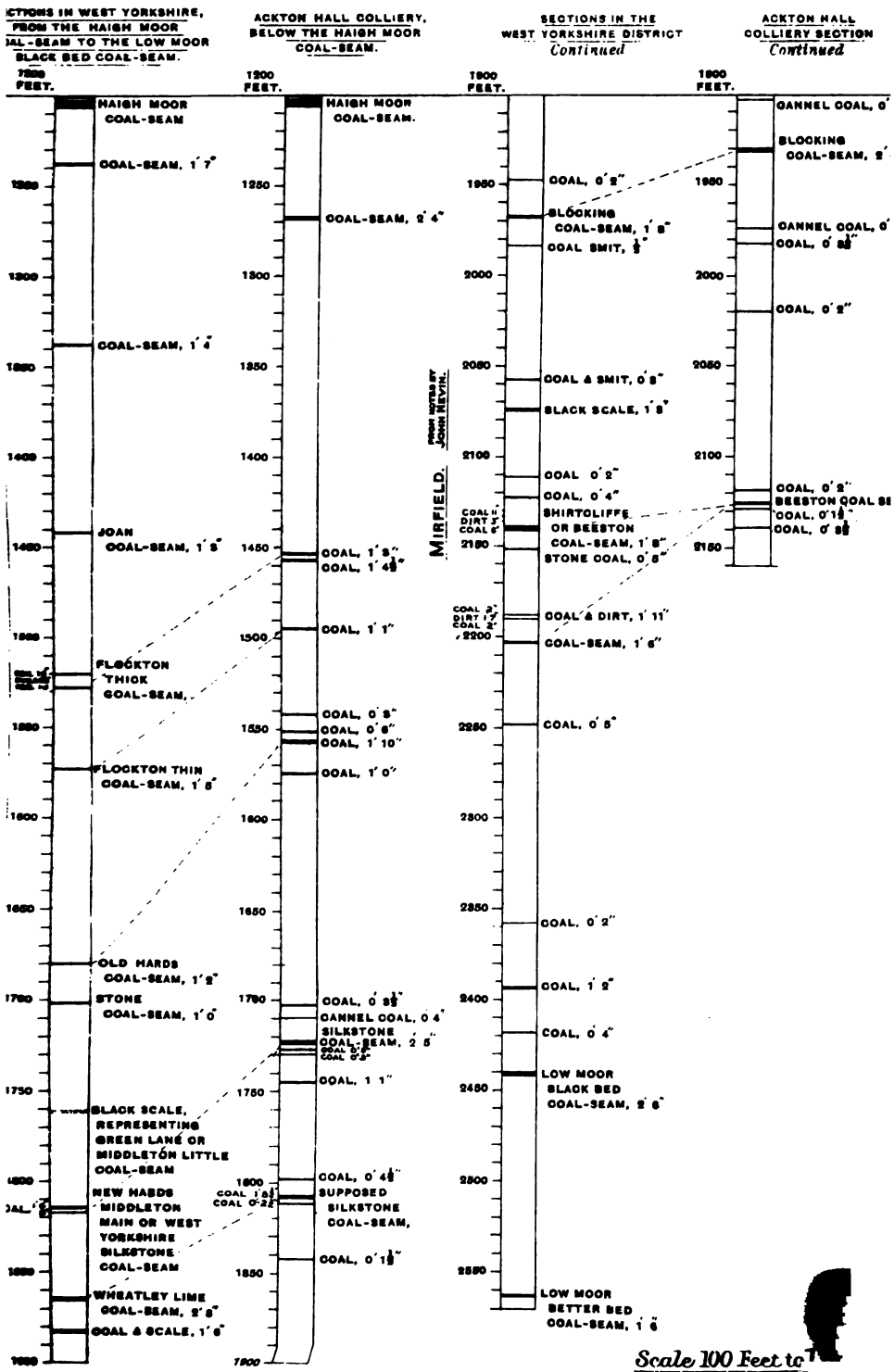
DISCUSSION ON PROF. LEWES' PAPER ON "MINING EXPLOSIVES."*

Mr. Harold Bonser (Leeds) wrote, pointing out that tests in leaden blocks had operated unfairly with respect to carbonite and ardeer powder; for instance, 1 ounce of bellite had been taken to be equal to 3¾ ounces of ardeer powder,† the proper proportion taken from practical tests in

* *Trans. Fed. Inst.*, vol. ix., page 320; vol. x., page 454; and vol. xi., page 121.

† *Report of the Proceedings of the Flameless Explosives Committee*, N.E. Inst., page 17.

To illustrate Discussion upon Mr. H. St. John Durnford's "Notes on the Sinking of the Ackton Hall Colliery" &c.


SECTIONS IN WEST YORKSHIRE, FROM THE HAIGH MOOR COAL-SEAM TO THE LOW MOOR BLACK BED COAL-SEAM.
ACKTON HALL COLLIERY, BELOW THE HAIGH MOOR COAL-SEAM.
SECTIONS IN THE WEST YORKSHIRE DISTRICT Continued
ACKTON HALL COLLIERY SECTION Continued
FEET.
HAIGH MOOR COAL-SEAM
COAL-SEAM, 1' 7"
COAL-SEAM, 1' 4"
JOAN COAL-SEAM, 1' 8"
FLOCKTON THICK COAL-SEAM,
FLOCKTON THIN COAL-SEAM, 1' 6"
OLD HARDS COAL-SEAM, 1' 2"
STONE COAL-SEAM, 1' 0"
BLACK SCALE, REPRESENTING GREEN LANE OR MIDDLETON LITTLE COAL-SEAM
NEW HARDS MIDDLETON MAIN OR WEST YORKSHIRE SILKSTONE COAL-SEAM
WHEATLEY LIME COAL-SEAM, 2' 6"
COAL & SCALE, 1' 6"
COAL-SEAM, 2' 4"
COAL, 1' 8"
COAL, 1' 4½"
COAL, 1' 1"
COAL, 0' 8"
COAL, 0' 6"
COAL, 1' 10"
COAL, 1' 0"
COAL, 0' 8½"
CANNEL COAL, 0' 4"
SILKSTONE COAL-SEAM, 2' 5"
COAL, 1' 1"
COAL, 0' 4½"
SUPPOSED SILKSTONE COAL-SEAM,
COAL, 0' 1½"
MIRFIELD.
COAL, 0' 2"
BLOCKING COAL-SEAM, 1' 8"
COAL SMIT, 1"
COAL & SMIT, 0' 8"
BLACK SCALE, 1' 8"
COAL 0' 2"
COAL, 0' 4"
SHIRTCLIFFE OR BEESTON COAL-SEAM, 1' 8"
STONE COAL, 0' 6"
COAL & DIRT, 1' 11"
COAL-SEAM, 1' 6"
COAL, 0' 6"
COAL, 0' 2"
COAL, 1' 2"
COAL, 0' 4"
LOW MOOR BLACK BED COAL-SEAM, 2' 6"
LOW MOOR BETTER BED COAL-SEAM, 1' 6"
CANNEL COAL, 0'
BLOCKING COAL-SEAM, 2'
CANNEL COAL, 0'
COAL, 0' 2"
COAL, 0' 2"
BEESTON COAL SE
COAL, 0' 8"
Scale 100 Feet to

the mine being 1 ounce of bellite to 2 ounces of ardeer powder. The following table represents the relative strengths of tamped explosives in practical working :—

	Ounces.
Bellite	1
Carbonite	1¼
Ardeer powder	2
Blasting powder	3

The paper by Mr. Winkhaus on "The Blasting Efficiency of Explosives,"* in some measure bears out the above opinion.

The following table recording the approximate composition of the various explosives is intended to show that British made explosives are more safe than those manufactured on the continent :—

Made in Germany.	Per Cent.	Made in Great Britain.	Per Cent.
Wetter dynamite—		Ardeer powder –	
Nitro-glycerine	52·9	Nitro-glycerine	33
Sulphate of magnesium or Epsom salts	32·7	Sulphate of magnesium ...	50
Kieselguhr	14·4	Nitrate of potassium ...	5
		Kieselguhr	11
		Chalk	1
	100·0		100
Kohlen-carbonite –	Per Cent.	Carbonite—	Per Cent.
Nitro-glycerine	25·0†	Nitro-glycerine	25
Nitrate of potassium ...	34·0	Nitrate of potassium ...	30
Nitrate of barium ...	1·0	Nitrate of barium ...	4
Rye-meal	38·5	Oak-bark	40
Wood-meal	1·0	Chalk	1
Bicarbonate of sodium ...	0·5		
	100·0		100

The writer agrees with Messrs. H. Hall and J. S. Martin in their conclusion that safety-explosives "should be used between shifts in the absence of the workpeople, or the vicinity of each shot should be made damp by copious watering," and would further suggest that the shot-hole itself should be thoroughly syringed out at the same time, so as not only to remove the boring dust but to fill up all the interstices in the coal or roof with water, so that a cooling film of water would be interposed between the flame of the shot and the atmosphere, in the case of a break, and the sides of the borehole would thus have a greater cooling effect on the gases created by the shot. It may be said that nitrate-of-ammonium explosives would

* *Trans. Fed. Inst.*, vol. x., page 264.

† The chemical analysis of a sample showed that the proportion of nitro-glycerine was 29·5 per cent.

probably suffer from this dampness, but, on the other hand, carbonite and ardeer powder would not do so, but would explode under water, if fired within reasonable limits of time.

In the writer's opinion, a perfectly safe mining explosive has yet to be manufactured, and under these circumstances, it naturally follows that mechanical methods must be resorted to in this direction. Nothing safer has been employed than the water-cartridge or the gelatinous-cartridge, which cools and purifies the gases. The Settle water-cartridge and the Heath and Frost gelatinous-cartridge have never yet been known to cause an ignition of gas or coal-dust, although continuously in use in the most fiery and dusty mines.

The writer would suggest that, in the next experiments that are made, the committee of the North of England Institute of Mining and Mechanical Engineers should extend their observations to the firing of explosives surrounded by water, and he has little doubt that the problem of complete safety would then be solved.

It was mentioned in the discussion that Prof. Lewes showed that a small quantity of carbon monoxide would make a mixture of coal-dust and air very explosive, and that by igniting carbonite in a small bomb, and by sprinkling coal-dust into a mixture of the resulting gases with air the whole was readily ignited by a lighted match.* The experiments carried out by the committee of the North of England Institute of Mining and Mechanical Engineers do not entirely confirm this experience, and after all actual experiments outweigh all theories. It is, however, true that gunpowder is a much greater offender than any of the high explosives producing carbon monoxide after ignition, and with any high explosive the quantity of carbon monoxide produced by a shot is perfectly inappreciable in a working-place.

The writer is of opinion that the conclusions of the committee of the North of England Institute of Mining and Mechanical Engineers are of greater value than Prof. Lewes' theoretical reasonings.

Mr. G. B. WALKER referred to Prof. Lewes' statement,† and said that the discussion arose on the subject of blown-out shots. It was assumed that where a shot was blown out in a position where a quantity of fine dust was suddenly thrown into the air, the carbon monoxide, however small the quantity, was projected with force out of the shot-hole, together with flame, a condition of things which would start a coal-dust explosion would be at once set up, and coal-dust was sufficient to spread the explosion as far as dry coal-dust existed.

* *Trans. Fed. Inst.*, vol. x., page 457. † *Ibid.*

Mr. O'SHEA said he should like to remark in reference to Prof. Lewes' statement, that carbon monoxide was a much more explosive gas than was generally recognized, and this had been remarkably demonstrated by Prof. Dixon, who in his work on "The Rate of Explosions in Gases,"* had shown that it was possible to get a most violent explosion with a mixture of carbon monoxide and oxygen, provided that the gallery in which the explosion took place was long enough for an explosive wave to be produced. If an explosion was started in a vessel of short length practically little or no violence took place—whatever did take place would be of very moderate character—but if the vessel was of sufficient length to enable an explosive wave to be set up, a violent explosion took place. Further, if the presence of carbon monoxide does increase the sensibility of coal-dust and air to explosion, it must be remembered that this gas is one of the products of the distillation of coal, and if the flame from the explosion of a shot, shooting into a dust-laden atmosphere, was to heat the dust sufficiently to cause distillation, carbon monoxide would be produced, and the conditions of increased sensitiveness result.

Mr. H. BONSER remarked that to talk of the danger of carbon monoxide after firing gunpowder in the pits for hundreds of years, appeared to him like locking the stable-door when the steed was stolen—it was beyond the bounds of practical enquiry, and merely the theory of a professor.

The meeting was then closed.

---

* *Trans. Fed. Inst.*, vol. iii., page 312.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, MAY 11TH, 1896.

MR. E. B. WAIN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

TECHNICAL INSTRUCTION.

The PRESIDENT called attention to a circular which had been received from the Technical Instruction Committee of the Staffordshire County Council, stating that they offered for competition two mining scholarships, each of the value of £30, and tenable at approved colleges or mining schools for two years.

DISCUSSION ON MR. T. H. ARMSTRONG'S PAPER ON "THE ROCKET OIL-ENGINE."*

Mr. ARMSTRONG exhibited and described a Rocket oil-engine in motion. He explained the facilities for cleaning the engine, and directed attention to the means of eliminating the exhaust gases.

The PRESIDENT said that there was one point he gathered from the explanation given by Mr. Armstrong—that it was possible to construct the ignition-arrangement so that it might be worked without any external flame or spark for use underground.

Mr. ARMSTRONG said that the firing arrangement could be effected either by an electric spark, or there could be a plate fixed. Oil-engines required to be heated by some means before starting. Of course in dangerous mines the heating would be dangerous, and prevent its use underground, but if that difficulty could be overcome, the subsequent ignition of the gases in the cylinder could be produced either by the electric spark or a

* *Trans. Fed. Inst.*, vol. x., page 473.

bull's eye, which was kept hot enough to heat the subsequent charges by the explosions themselves. It was possible to start the engine without any flame outside; but to do that they must start the engine with methylated spirits or some similar highly inflammable material. That was if they had an electric spark, and before turning on the oil they filled a small vessel with methylated spirit. They would get twenty or thirty impulses; and having got that, they could then turn on the oil. The Rocket oil-engine was one of the oldest oil-engines, or rather the principle on which it worked was old. It had the ordinary Otto cycle. He (Mr. Armstrong) thought that in this country there were over 2,000 petroleum engines at work, and about 1,000 in use abroad.

Colonel STRICK moved a vote of thanks to Mr. Armstrong for showing the Rocket oil-engine in motion. He thought that an intelligent mechanic or labourer might manage it.

Mr. R. H. COLE seconded the resolution, which was carried unanimously.

DISCUSSION ON MR. J. J. PREST'S PAPER ON "MODERN COAL-TIPPLERS."*

The PRESIDENT said that Mr. Prest had described eight types of coal-tipplers, three of which had been designed and constructed in the immediate neighbourhood of North Staffordshire. All the tipplers that he had described were driven by power; some were rather complicated; some were extremely simple. But it appeared to him that two of the tipplers were absolutely reliable in their working, and both of those were with positive action; these were the Wood and Burnett and the Heath and Woodworth tipplers—one of them being a side-tippler, and the other an end-tippler. The advantage of these tipplers was that there was a certain positive speed at which the coal might be turned over; and no matter how careless the man in charge might be, the tippler could only go at a particular speed. He had used a Silvester tippler, with simple friction-gear attached, that had tipped 1,000,000 tons of coal and cost nothing for repairs; and he had no doubt that other types of tipplers would be equally economical in working.

Mr. J. J. PREST said that the Wood and Burnett tippler was driven by a friction-clutch; and all the power-driven tipplers were positive-driven tipplers in that sense.

* *Trans. Fed. Inst.*, vol. ix., page 231.

The PRESIDENT said his impression was that the Wood and Burnett tippler (as described in Fig. 7, Plate XIV., Vol. ix.) was driven by a chain, and not by a friction-roller, as in the other cases.

Mr. PREST said that it was driven by an ordinary friction-clutch, sprocket-wheel, and chain.

The PRESIDENT observed that the speed of the Wood and Burnett tippler was regulated and governed by a sprocket-wheel and chain in the same way as the Heath and Woodworth, was governed by cogwheels and a rack that was thrown into gear.

Mr. PREST said that once they put the Wood and Burnett tippler into gear the speed of tipping coal must be uniform ; and so it was with all the power-driven tipplers.

Mr. B. WOODWORTH said that power-driven tipplers should be positive-driven, and provision should be made to slip when serious obstructions were encountered. The Wood and Burnett tippler slipped on the friction-clutch, while the Heath and Woodworth driving-chain slipped on the wheels and prevented breakages. Although steady tipping was very desirable, in many cases it was considered unnecessary to incur the extra cost as compared with hand-tipping machinery, as great quantities were got through in the ordinary way with facility.

The meeting was then closed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 25TH, 1896.

MR. THOMAS DOUGLAS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 28th and that day.

The proceedings of the Council of The Federated Institution of Mining Engineers were reported.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOHN ASHWORTH, Mining Engineer, 8, King Street, Manchester.

Mr. JOHN E. BREAKELL, Mining and Metallurgical Engineer, Transito Mine, Ibaqué, Tolima, Republic of Colombia, South America.

Mr. J. PARKE CHANNING, Consulting Engineer, 34, Park Place, New York City, U.S.A.

Mr. WILLIAM JOHN CHARLTON, Engineer, Ashington Colliery, Morpeth, Northumberland.

Mr. WALTER CURRIE, Mining Engineer, P.O. Box 102, Bulawayo, Rhodesia, South Africa.

Mr. GEORGE WILLIAM EUSTICE, General Manager of the Frontino and Bolivia Gold Mines, 184, Gresham House, Old Broad Street, London, E.C.

Mr. ALBERTO FIGARI, Mining Engineer, Apartado No. 255, Lima, Peru.

Mr. F. G. de VISME GIPPS, Mining Engineer, Coolgardie, Western Australia.

Mr. J. B HOBSON, Mining Engineer, Cariboo Hydraulic Mining Company, Limited, Vancouver, British Columbia.

Mr. ALGERNON EDWARD JOHNSON, Civil Engineer, County Court Buildings, Wrexham.

Mr. HENRY MELLON, Mining Engineer, Brook Lea, Askam-in-Furness.

Mr. FRANK REED, Government Inspector of Mines, Perth, Western Australia.

Mr. JOHN BASELEY SELBY, Mining Engineer, Leigh, Lancashire.

Mr. WILLIAM THOMLINSON, General Manager for the Seaton Carew Iron Company, Limited, Seaton Carew, R.S.O.

ASSOCIATE MEMBERS—

Dr. CHARLES CHEWINGS, Geologist, Coolgardie, Western Australia.

Mr. ALBERT SPENCER ELLAM, General Manager, West Australian Gold Concessions, Limited, Coolgardie, Western Australia, and 33, Old Broad Street, London, E.C.

Mr. T. SIDNEY HARGREAVES, Institute of Mines and Forests, Georgetown, British Guiana.

Mr. FREDERIC O. KIRKUP, Colliery Manager, Bitchburn Colliery, Crook, R.S.O.

Prof. HJ. SJÖGREN, Osmo-Nynas, Sweden.

Mr. HENRY TIMES, Deputy Chairman, West Australian Gold Concessions, Limited, 33, Old Broad Street, London, E.C.

ASSOCIATE—

Mr. JOHN LIGHTLEY, Deputy Overman, Shire Moor Colliery.

BRANCEPETH COLLIERY ACCIDENT.

The PRESIDENT, alluding to the recent deplorable accident at Brancepeth colliery, proposed a vote of sympathy and condolence with the relatives of the unfortunate workmen who had been killed or injured, with the owners of the colliery, and with the agents, who had endeavoured to secure the safety of the workmen as far as possible.

Mr. T. W. BENSON seconded the motion, which was unanimously adopted.

DISCUSSION ON MR. JOHN JAMESON'S PAPER ON THE "RECOVERY OF BYE-PRODUCTS IN THE MANUFACTURE OF HARD COKE."*

Mr. HENRY AITKEN (Falkirk) wrote, with reference to Mr. Jameson's statement that the Aitken coke-ovens were worked under pressure (thereby inferring that the pressure forced the gases out at the bottom of the oven, and that the products of combustion passed through the coke), that it was incorrect. When he (Mr. Aitken) first worked his ovens, they were worked by drawing off a portion of the gases from the bottom of the oven, and burning the remainder of the gases at the top, in the usual manner. This was what he understood Mr. Jameson called his method; but he (Mr. Aitken) worked ovens in this manner years before anything was known of the Jameson process. The results got by working in this way were not so good as he desired, and he improved the quality of the coke by

* *Trans. Fed. Inst.*, vol. x., page 330.

consuming a portion of the gases on the top, by forcing in heated air at numerous small holes round the top of the oven, and so coked the coal, the air being heated by the heat in the coke-oven gases before going into the oven, no air being allowed to come down on the coke in the oven. This modification gave much better coke, but the yield of ammonia and oil was not so high as he had anticipated, so he drew the whole of the volatile gases down through the hole in the bottom of the oven, and condensed and scrubbed the ammoniacal liquor and oil from them, and sent the gas back into the top of the oven, introducing it at numerous small holes under the air-holes. In this way the coke made was perfect, the temperature being very high, and the yield of bye-products and coke much increased.*

Mr. JOHN JAMESON wrote that Mr. Aitken appeared to cast a doubt upon the novelty of the Jameson process, if not to deny it altogether. He had only to remark that, if Mr. Aitken could have demonstrated what he now appeared to assert, he would have voided the Jameson patent in the very height of its apparent success. Mr. Aitken was present at the reading of his (Mr. Jameson's) paper before the Iron and Steel Institute in 1883, and (he believed) took part in the discussion upon it, and, like all other enquirers, was supplied with all possible information. There is, however, one other point which is not irrelevant. If Mr. Aitken, as he says, worked the Jameson process, he could not have escaped the difficulties which for years hindered its commercial success, unless he had some means which are yet undisclosed of overcoming these difficulties. He might add that his experimental oven was built and tried in 1854, long before (he believed) Mr. Aitken's first experiment.

DISCUSSION UPON THE "REPORT OF THE PROCEEDINGS OF THE EXPLOSIVES COMMITTEE."†

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) desired to point out that his remarks, recorded on page 492,‡ had been slightly misunderstood by Mr. Hedley. He did not for a moment wish for an inference to be drawn from his remarks "that although the committee succeeded in producing ignitions of gas or coal-dust under certain conditions in their apparatus, it did not follow that they could do so in a mine,"§ and in fact

* *N.E. Inst. Trans.*, vol. xxv., page 97; and vol. xxix., page 81.

† *Trans. Fed. Inst.*, vol. viii., pages 227 and 593; vol. ix., pages 115, 206, and 274; and vol. x., pages 38, 197, 492, and 503.

‡ *Ibid.*, vol. x. § *Ibid.*, page 496.

his remarks have exactly the opposite meaning, for he stated that although the Blackwell colliery-dust was not fired in the experiments made by the Chesterfield and Midland Counties Institution of Engineers, yet the disastrous experiment on a natural scale showed how unreliable the experiments had been, and that experiments conducted under natural conditions might be far more liable to result in ignition than experiments artificially made.

The "many self-evident reasons" why strangers should not be introduced to the proceedings are clear to all, but there does not appear to be any such reasons why members or makers of the explosives—experts in their use—should not have been permitted to see the experiments.* It certainly might have prevented incomplete records being given in the *Report* "owing to absence of observers," and it probably would have ensured that explosives supplied by makers, and fired under their own conditions as to detonators and rules as to firing, might have given different results. It would have left makers of explosives no loophole with respect to the quality and conditions they impose upon their use, and it would have proved whether explosives deteriorated by age. He (Mr. Stokes) would have obtained the explosives in both ways, viz., from collieries where they were in actual use, and from the makers, and, as stated by Mr. Hedley, "if they had in any way deteriorated before use"—"attention should be drawn to this fact." But how could such deterioration be ascertained unless samples, freshly made and obtained direct from the makers, were fired as well as samples from mines where such explosives are used? If makers had been given an opportunity of witnessing the experiments made with their own explosives, it might have been beneficial in the way of suggesting to them such alterations in the composition or preparation of their explosives as would improve the mixture, and thus assist in giving us what is asked for, viz., a safety-explosive. All previous experimenters, both at home and abroad, appear to have been only too pleased to allow mining engineers to witness the experiments. However clearly the experiments may be recorded, yet visual experience would be more convincing.

The large number of experiments already made, both at home and abroad, and the volumes of literature published upon the question appear to be quite sufficient to form the groundwork for remedial measures, and it is in this direction that those having the care and direction of mines might now beneficially direct their attention.

Mr. BIGG-WITHER (Wigan) wrote that the Roburite Explosive Company had adopted the suggestion of the Explosives Committee, and are

* *Trans. Fed. Inst.*, vol. x., page 496.

now labelling each 5 lbs. packet with the composition of the explosive contents. The company had for some time past been marking the packets with the number of mixing and date of packing, and the present addition will complete the suggestions of the committee.

Without going into the whole report, he (Mr. Bigg-Wither) would like to say a few words, especially concerning the experiments with coal-dust in suspension without gas, and particularly as to the results with carbonite and roburite. He mentioned these two explosives because they were the only two of those tested which were put through the full series of tests. The committee appeared to have laid down a rule that a certain maximum number of shots should be fired in each series, and that no further shots should be fired as soon as an ignition occurred. In the case of roburite, however, fired into coal-dust in suspension, the maximum limit seems to have been exceeded, and no fewer than 52 shots were fired without causing an ignition. These results are highly satisfactory, but should an ignition have occurred, after the fixed maximum number had been fired, such an extension of the experiments would have been unfair upon the particular explosive.

As the committee departed from the lines laid down in this particular instance, it would have been more satisfactory if they had made a similar exception in the case of carbonite, and continued up to the maximum number of shots in spite of the ignition in coal-dust having occurred at the first shot, particularly as carbonite had showed up so well in the gas experiments.

With the ignition of coal-dust in suspension at the first shot by 2½ ounces of carbonite, the committee leave the matter standing; but in a report recently issued by two of H.M. Inspectors of Mines on experiments made in Germany,* it is stated that no ignition of coal-dust by carbonite, even with charges of 18 ounces, had ever occurred. Comparing these two very opposite results, one would say that there must be something wrong, and as the writer had an apparatus at his disposal, he resolved to test the matter himself.

The apparatus used may be described as part of a cylindrical boiler, 3 feet in diameter, sunk vertically into the ground: within which is suspended a steel cannon, whose mouth is 7 feet from the top of the apparatus. The upper 4 feet of the apparatus is made of loose plates bolted together, forming a cylinder of rather a larger diameter than the boiler, and this affords an air-inlet all round.

* *Trans. Fed. Inst.*, vol. ix., page 250.

In making the tests no special arrangements are made to close the top of the apparatus or to measure the quantity of dust. The dust is simply blown into the cylinder about 4 feet above the mouth of the cannon by means of a fan, and the shot is fired a few seconds after the dust is seen issuing from the top of the apparatus, and any ignition which occurs is plainly visible. In the experiments made so far, he had used 6 ounces charges of carbonite (made in Germany) obtained from a neighbouring colliery. The charge was placed in the steel cannon, without stemming, and the top of the charge was 16 inches from the mouth of the borehole; two or three different kinds of coal-dust have been used, some from the Wigan district, and some from Whitehaven. In all 55 shots have been fired on 8 separate days, resulting in 22 ignitions. On one day there were 10 shots without any ignition, whilst on another day there were 5 ignitions in 5 shots.

The writer considers that these results fully confirm the theory advanced by Prof. Lewes in his paper on "Mining Explosives."* Up to this time it was thought that gas was more sensitive to ignition than coal-dust, but with carbonite the contrary is the case. The writer's experiments tend to confirm the results obtained by the Explosives Committee, and he is inclined to think that the reason for the opposite results in the German experiments will be found in the weight of charge used, or in the apparatus itself. He does not venture to speculate as to the exact cause, whether insufficiency or stagnation of air or vitiation of the chamber by the products of combustion of the carbonite. He has always been of opinion that the Explosives Committee were working on the right lines in testing with small charges, as if a small charge will ignite an explosive mixture, one would certainly expect a larger charge to do so more easily.

Mr. C. C. LEACH, referring to Mr. Stokes' remarks, said that if the makers of the explosives had been present at the experiments the enquiry could not have been considered so independent as it was. Mr. Stokes was under a misapprehension as to members of the Institute not being allowed to attend, for they had been invited to do so since February 2nd, 1895.

The SECRETARY read the following paper by Mr. William Blakemore on "Coal-cutting by Machinery":—

* *Trans. Fed. Inst.*, vol. ix., page 320.

COAL-CUTTING BY MACHINERY.

By W. BLAKEMORE, Vice-President of the Mining Society of Nova Scotia.

Introduction.

The subject of coal-mining by machinery must on all grounds be considered one of the most important topics of the moment. Of late years the force of competition, both at home and abroad, together with the depressed condition of the coal and iron industries, has made it a matter of increased importance to consider any and every means that would tend, however slightly, to reduce the cost of mining coal. The chief result of these conditions has been to develop enormously the use of all kinds of mechanical appliances, for in this, as in every other industry, in spite of the opposition which has invariably met the introduction of new machinery, it has eventually been fully established that a good machine both increases the production and reduces the cost of the article manipulated.

No class of machine has met with more hostility at the moment of its introduction than coal-cutting machinery, and so strong and persistent has been the opposition that, had it not been for the reasonable forbearance and patience of those who had confidence in the result of their experiments, there is little doubt that coal-mining by machinery would have been almost as puny an infant in other countries as it is at the present moment in Great Britain. Quiet persistence and intelligent perseverance have won the day, and within the last ten years it has been fully demonstrated upon the continent of America that suitable machines are in the market for cutting coal under almost any existing condition to greater advantage than by the old and laborious method of hand picks. The writer has no doubt that, in spite of the conservative views of his fellow-countrymen, it is only necessary for them to become fully acquainted with these machines, and with their entire adaptability to the requirements of mining in Great Britain, to ensure their ready acceptance and to inaugurate an era of cheaper mining that will to some extent lighten the burdens under which colliery proprietors have unfortunately been groaning for the last few years.

It has been the writer's good fortune since 1893 to be connected with the Dominion Coal Company, a corporation possessing both the capital and the enterprise to give a thorough and exhaustive trial to the best modern appliances obtainable. In connexion with coal-cutting by machinery, the writer thinks he may fairly claim that they have gone into the matter, and fully tested the capacity and the value of this system of mining more thoroughly than perhaps any other firm. In saying this, he is not unmindful of the fact that an enormous tonnage of coal is cut by machinery in Pennsylvania, Ohio, and other American states, but the company have been privileged to test a greater variety of machines, and especially to secure the first longwall mining machine made upon an entirely new plan (the Mitchell), which bids fair to outstrip any of its competitors.

Out of nine working mines, the company are using machines at five, having upwards of seventy working. For the purposes of this paper, the writer thinks that it will be more profitable if he confines his remarks to the operations at the Dominion No. 1 mine, because it is a new one, especially laid out for the purpose of machine-mining, and the whole of the work, including the driving of headings, widening of haulage-roads, and opening up of working-places, has been done entirely by one or other of the machines to be hereafter described.

Motive Power.—It would be interesting to give some account of the surface-works in connexion with the inauguration of this system, but the writer must be content with briefly stating that the motive power originates with a battery of three Babcock and Wilcox boilers, each of 210 nominal horse-power, and working at a pressure of 100 pounds per square inch. One boiler supplies steam for the hoisting-engines, fan, pump, etc.; and the other two for the air-compressors. The latter are very massive, and replete with the latest improvements, Corliss valves, etc. The air-compressors were manufactured by the Ingersoll Rock-drill Company of Canada, and are compound, the high-pressure cylinder being 22¼ inches in diameter and 42 inches stroke, and the low-pressure cylinder 44 inches in diameter and 42 inches stroke.

The combined indicator-diagrams of the high and low-pressure cylinders, show a very satisfactory efficiency, that of the engine being 94 per cent., and of the air-compressor 77 per cent. The valves of the high-pressure cylinder cut off rather too soon, causing a loop in the low-pressure indicator diagram, but with a slight readjustment, which has since been made, the results are perfectly satisfactory. The air is maintained at a steady pressure of about 80 lbs. per square inch.

The air after being compressed is passed through a series of large pipes underneath the floor of the engine-house and between the foundations. This space is kept full of cold water, constantly circulated by means of a small pump, and the air when it passes into the mine is quite cold, its temperature being about 50 degs. Fahr.

The circulating pipes are 12 inches in diameter, and the main column of pipes leading from the engine into the mine is a wrought-iron tube (8 inches in diameter) with flanged joints. This main-pipe is carried down the north deeps for a distance, at present, of 2,000 feet, and down the south deeps for a length of 1,000 feet. Thence a pipe (4 inches in diameter) branches along the south levels for a distance of nearly 2,000 feet, and from this pipe, at various stations, there are branch pipes (2 inches in diameter) conveying the air into the working-rooms. At the bottom of the deep, there is a cylindrical air-receiver *E* (13 feet long and 2 feet in diameter) and at a point 1,000 feet down the deep, there is an air-receiver *B*, (10 feet long and 4 feet in diameter). The air when delivered at the working-places is dry, a temperature of 48 degs. Fahr., and a pressure varying from 2 to 3 pounds less than that at the air-compressor.

Up to the present time, it has only been found necessary to work one air-compressor, the number of machines operating in the mine not exceeding twenty. The capacity of each air-compressor is estimated at nearly double this. In fact, a Stanley header, a longwall machine, a pump, and three or four boring-machines have already been worked at the same time as twenty coal-cutting machines, by one air-compressor.

A general idea of the plan of the mine, and the mode of producing the power required, is illustrated in Fig. 1 (Plate XIII.).

Description of Coal-seam.—The mine is opened in the Phalen coal-seam, which is semi-bituminous, hard in the holing, with a quantity of iron pyrites running at the base of the seam. The thickness varies from 8 to 8½ feet, and the dip is uniformly 1 in 14.

Stanley Header.

The Stanley heading-machine, being familiar to many of the members, will need little description.* This machine was used in driving the main roads from the shaft on the south side. There were two machines, each with cylinders 8 inches in diameter by 6 inches stroke, and making 250 strokes per minute, under a working-pressure of 80 pounds to the square inch. The weight of each of these machines, without the conveyor, was

* *Trans. Fed. Inst.*, vol. i., page 124.

4,000 pounds. As the main haulage-roads from the shaft were driven on the full dip of the seam, considerable quantities of water had to be overcome, greatly impeding the working of the machines, and reducing the rate of progress very much below what it usually is upon a level. When working, it averaged about 15 feet per shift of eight hours. This progress, however, would have been much less but for the excellent addition recently made to the Stanley header, in the shape of a conveyor, which catches the coal at the face, elevates it to the tail-end of the machine, and that at sufficient height to dump it automatically into the tubs. Fig. 2 (Plate XIII.) shows the machine and the conveyor. When the Stanley header turned off at 1,000 feet from the shaft to work upon the south level, the result was very different, an average length of about 20 feet per shift being made; and, as testing the utmost capacity of this machine, it may be interesting to know that a record run was made of 30½ feet in eight hours. The diameter of the bore was 6 feet, and three men were required in attendance, two at the face and one at the tail of the machine. The blast was made after every 2 feet of cut.

After two years' experience, and constant use of the Stanley heading-machine, the writer is of opinion that for rapid driving under favourable conditions, such as are found in a level seam of coal, and little or no water, nothing can compete with it. The speed which can be maintained is extraordinary, and the circular cut gives such a strong passage with the minimum of friction for the ventilating air-current. On the other hand, the weight of the machine makes it very expensive to move. The moment it ceases boring coal trouble begins, as it takes a large gang of workmen to dismantle and move it around. It also refuses to proceed at the first sign of material stronger than the coal in which it is working. In such a case, and in the event of unevenness in the floor of the seam, there is no alternative but to draw it back, and cut through the difficulty by some other means.

It is necessary also that the coal-seam shall be thicker than the diameter of the cut; unless the roof or floor be softer than the coal, in which case, of course, part of the cut can be taken in that. This, however, means spoiling all the slack that is made in cutting. The last difficulty experienced with the Stanley header is not fairly chargeable to the machine, but is the result of other conditions, viz., that if a double haulage-road be required, say for the endless-rope system, or wide enough to pass-by, when the Stanley machine has finished its work, the initial stage only is completed, and the widening-off process has to be performed either by hand or by some other machine.

The writer is of opinion, from his own experience, having regard to the numerous delays resulting from the causes previously stated, that it is possible in any case where a double-road is required, to complete it as expeditiously and at less cost with one of the percussion-machines than by using the Stanley header in the first instance. There is also the further consideration that in no large mine would a circular road (6 feet in diameter) be sufficiently large for ventilating purposes, even into one principal district. At the Dominion No. 1 mine, it has been found necessary to enlarge the lower level, which was driven by the Stanley header of the size stated, and which is used solely for ventilating purposes.

Mitchell Longwall Machine.

The Mitchell longwall machine has been recently invented, and the one used at the Dominion No. 1 mine is the first made. The writer considers it to be the best longwall machine yet invented, especially suitable for use in many British mines, and he will therefore give a somewhat detailed account of its construction. This machine is the joint production of an American engineer, Mr. J. L. Mitchell, and the Sullivan Machinery Company. Its weight is 4,000 pounds. It has two cylinders, each 6 inches in diameter, by 8 inches stroke, and the normal rate of working is 250 strokes per minute, with an air-pressure of 80 pounds to the square inch.

The machine propels itself along the face, making an undercut either in the coal or in the fireclay, or similar soft material underneath, by means of a projecting bar or arm, and a revolving chain, cutters being fixed in the links of the chain. The bar projects at right angles from the side of the machine, and may be regulated to any depth of cut from 3 to 6 feet, but the writer has found in practice that 5 feet is the maximum safe cut to make with the present machine. The vertical height of the cut is about $3\frac{1}{4}$ inches, and this represents all the slack which is made in process of working.

The machine, although heavy, is not bulky, being compactly built. It will pass through an opening 30 inches high and 30 inches wide; but in a longwall face, where cogging is resorted to, it would be safe to reckon that it would work comfortably in a space 4 feet from the cog timber to the face of the coal. There is a novel steering device (Fig. 3, Plate XIII.) attached to the rear of the machine, which enables it to follow a face not perfectly straight in track, if required, as the machine is kept up to the face by means of a lever attached to the steering-gear.

The machine is mounted upon a shoe 2½ feet wide and 7 feet long. The feed-drum is 20 inches in diameter, and constructed to hold 200 feet of ½ inch wire-rope, which is attached to an anchor post set at such a distance in front as the rope will reach. The machine can be advanced the full length of the rope without stopping. It requires the services of two workmen, one in front to see that the rope winds regularly upon the drum, and to clean away any small coal that may have collected in advance of the cut. The foreman has charge of the machine, remaining at the rear so as to control the throttle and steering-gear lever, and at the same time he closely observes the running of the machine.

The engine is enclosed. The gearing runs in oil, so that there is very little danger of dust working into and cutting the movable parts. The power is transmitted through spur and bevel-gear wheels to the chain. A sprocket wheel located near to the shoe, maintained upon a vertical shaft, drives the cutter-chain. An idler-wheel is arranged with an oil receptacle in the hub to carry the chain around the end of the bar. The face of the bar is protected with hardened tool-steel. The chain links are made of malleable iron with steel links and rivets, each 1 inch in diameter, so as to give strength and durability to the chain. The friction-clutch is arranged in the drum so that it can be thrown out of gear, and in order that any desired tension can be maintained.

The machine, of course, will cut in only one direction, and, unless it is possible to continue around the face in a circular route, it is necessary to haul it back to the starting point for the next cut. Although it will make itself an undercut, the writer does not consider it desirable to impose this strain upon the machine, as the resultant gain is very slight. It is better to cut the first opening by hand, and so insert the machine ready for its work.

The rate of progress is remarkable, the writer has repeatedly tested it, and finds that it will cut whilst in full work an average of 1 lineal foot per minute, but it is not desirable, nor indeed practicable, to keep it running under this strain, as at half the speed, or rather working half the time, it will undermine a sufficient quantity of coal to satisfy any reasonable requirements, and indeed as much as can be handled in any given district. If continued to run at top speed, the cutters become heated. The better plan is to let it run for ten or fifteen minutes, and then slow up. In this way, a uniform daily undercut has been maintained of about 200 lineal feet, 5 feet under, with the attendance previously specified.

As showing the utmost capacity of the machine, in one test run of eight hours, a cut was made of 300 lineal feet, 5 feet under; and with

another machine of the same make, the cut was 500 lineal feet, 3 feet under, in each case, working out to 1,500 square feet in eight hours. But the former figure is as much as can be relied upon in ordinary working.

It will be seen from these remarks that the Mitchell longwall machine is speedy, efficient, and economical, where the conditions are favourable for its use. Of course the flatter the seam the better. At the same time there is no doubt that it will work well on a slant, where the inclination is not too great, as the shape of the cutter tends to hold the machine to the face, and this tendency can be further increased by the aid of side jacks.

Like every other machine, it has its disadvantages. Weight is one, but this, however, is not so great an obstacle as might be imagined, and certainly much less than in the case of the Stanley header, as the machine is more compact, and the bulk considerably less.

Like the Stanley and all other rotary machines, it objects to foreign metal in the strata, and in case it meets with a piece of rock or anything materially harder than the coal, the cutters are apt to break or to refuse to make any progress. The same difficulty occurs when the floor of the mine is uneven, but by examining the face in advance, and noting the approaching inequality in the floor, the longwall machine can be made to mount the shoe, and to elevate the cut so as to pass over the obstruction, if the latter be not too high. It, however, sometimes happens that it is preferable to draw out the machine, and to cut past the obstacle by hand-labour.

There is a further disadvantage which must inevitably arise with all machines that only cut a narrow groove in the coal: viz., the narrowness of the cut prevents the coal from falling sufficiently to break it when blasted. Of course this disadvantage depends to some extent upon the texture and thickness of the coal, and it has been found necessary in the case of the Phalen coal-seam to wedge a piece, varying from 9 to 12 inches, from the upper side of the groove before blasting. This allows the coal to fall and topple over sufficiently to break it ready for loading. However, when all the disadvantages are weighed, there is no doubt that the facility with which this machine can be taken along a narrow face, the ease with which it is operated, and the low cost of attending it, stamp it as the machine of the future in any longwall working properly designed for the admission of mining machinery.

Ingersoll-Sergeant Machine.

The writer will now describe a different type of machine, the percussive, a comparatively light, portable, and cheap machine, designed for

room work, but, as circumstances have proved, equally applicable to narrow work or headings. Of this type, there are three varieties in use at the Dominion No. 1 mine, viz.: the G 4, improved Ingersoll-Sergeant, the Harrison, and the Yoch. The two former are so much alike (the only difference being in details of manufacture) that one description will answer for the two. The writer will therefore describe the Ingersoll-Sergeant machine, which came out at the head of the list in a severe test lasting a fortnight, conducted at the above mine in August, 1895.

This machine is illustrated in perspective in Fig. 4 (Plate XIII.) and in detail in Figs. 5, 6, 7, 8, and 9 (Plate XIII.).* Another view (Fig. 10, Plate XIII.) shows the position of the machine when shearing, or cutting vertically. The Ingersoll-Sergeant machine weighs 750 pounds. The cylinders are 4 inches in diameter and 11 inches stroke, and with a pressure of 80 pounds per square inch, the normal speed is 200 strokes per minute. This machine comprises a reciprocating drilling-engine, mounted upon a pair of wheels to enable the cutting tool to operate in horizontal, vertical, and oblique planes for under-cutting and for cutting around parts of coal, to facilitate the transportation of the machine from point to point, and to enable the direction of the cutting to be determined by the operator to produce any desired results.

The wheels upon which the drilling-machine is mounted, together with their mountings, are so constructed that their axes may be shifted longitudinally along the machine in order to balance its weight, and thereby facilitate its manipulation by the operator, as for example when a shorter or longer tool or tool-holder is employed. It also comprises an extension tool-holder with means for attaching and adjusting the handles by which the machine is manipulated.

The improved mining machine also comprises a novel construction and arrangement of valves for controlling the ingress and egress of the steam, air, or other fluid by means whereof the piston is propelled. The valves are duplex, and operated to open and close the steam and exhaust-

* The following references describe Figs. 5, 6, 7, 8, and 9:—1. Cylinder. 2. Piston (long). 3. Piston (short). 4. Extension. 5. Extension key. 6. Pick. 7. Pick key. 8. Front head (long). 9. Front head bushing (long). 10. Front head (short). 11. Front head bushing (short). 12. Front head bushing bolts. 13. Cup leather. 14. Cup leather washer. 15. Side rods and nuts. 16. Back head. 17. Back head buffer. 18. Back head buffer plate. 19. Front head washer. 20. Front head filler. 21. Cup leather washer screw. 22. Wheel. 23. Wheel trunnion. 24. Wheel trunnion bolt. 25. Wheel trunnion washer. 26. Wheel trunnion washer stud and nut. 27. Valve. 28. Valve chest. 29. Valve chest bolt. 30. Valve chest head. 31. Valve chest head bolt. 32. Valve plunger. 33. Valve seat. 34. Regulating screw. 35. Regulating screw gland. 36. Piston ring. 37. Piston ring spring. 38. Handle. 39. Handle bolt. 40. Socket wrench. 41. Throttle valve. 42. Front head cushion.

ports entirely independent of the motion of the piston, so that, even with the pick stuck in the coal, the valves would move and continue to open and close the ports of the engine, and a slight jar of the machine by the operator would free the pick and permit it at once to resume operations. An important advantage incident to the improved valve-motion is due to the fact that the travel of the valves is independent of the length of the stroke made by the piston. When the machine is moved up close to the work in commencing the cut, the stroke of the piston is very short, and the valves and piston may be caused to operate more rapidly and accomplish more strokes in a given time than would be the case if the valves and piston had to wait for the complete revolution or movement of some impelling mechanism.

The cylinder of the drilling machine is provided with the usual ports at the opposite ends of the cylinder, and also with an exhaust-passage. To the outer end of the main cylinder is attached a supporting or guide sleeve (front-head), provided with cuts at its outer extremity, and with clamping bolts (front-head bushing-bolts) passing transversely through the divided portion for the purpose of contracting them and securing a bushing (front-head bushing). The piston rod works through suitable packing in the forward-end of the cylinder, and is made long enough to project beyond the end of the sleeve (front-head) when fully retracted. At the forward-end of the cylinder is placed a buffer of leather of such construction as to form an air-cushion for the piston. The projected extremity of the piston-rod is tapered, so as to fit into a corresponding taper in an extension which is held in place by means of a wedge (extension-key) ; the outer extremity of the extension is adapted to receive the shank of the pick, which is secured in position by a wedge (pick-key). The extension may be made tubular for lightness and portability, and may be made in various lengths to adapt itself to any desired work or position. By reason of its extremely simple adjustment it can be readily attached or detached.

The piston-rod is provided with eight straight grooves engaging in similar projections in the end bushing for the purpose of preventing any undesired movement of the piston and pick. The improved pick is in the form of a tapering chisel, the end of which is provided with a V-shaped notch, having a sharp edge, and cutting points. This form is very easily sharpened and would remain sharp and do more work than the thin sharp edge frequently used.

The carrying-wheels (wheels) on which the machine is supported have adjustable trunnions (wheel-trunnions) upon which the wheels are

mounted. The increased size of the axes of the carrying-wheels is intended to develop friction between the wheels and their axles, and thereby add stability to the machine when in operation—that is, the recoil of the machine at each blow is opposed to the friction between the wheels and their axles, in addition to the inertia due to the weight of the machine, thereby diminishing the recoil and increasing the effective force of each blow.

On each side of the central portion of the cylinder an extension is formed, provided with a transverse slot or recess, leaving a narrower exterior opening, shoulders being formed by the front inner walls of the slot. The slot has a downwardly extending opening through which is inserted a short-headed bolt, the head of the bolt being retained in the slot by the shoulders, and the bolt is capable of longitudinal movement. The inner end of the trunnion fits against the projection on the cylinder, against which it is firmly held by the bolt which passes through it, and it is provided with a locking-nut at its outer extremity, which bears against and holds the trunnion firmly in position. The trunnion is further provided with smaller projections, which extend to the outer portion of the slot on each side of the bolt to prevent the bolt from dropping through the downward opening while being adjusted. To adjust the wheel with respect to the weight of the machine the nut is loosened, and the bolt can be moved longitudinally in the slot, carrying with it the wheel and trunnion, which latter is firmly locked in the desired position by tightening the nut.

The steam-chest is formed with a lateral extension forming longitudinal apertures to receive the shanks of the handle. The openings in the projections are formed by cores when the steam-chest is cast, and are sufficiently large to receive the shanks of the handles. The handles are secured in position by the toe-bolts (handle-bolts) which are inserted from below into the apertures for the handles and project upwards through the extensions, where they are fitted with screw-threaded nuts. The attachment of the handles is extremely simple, it being only necessary to loosen the bolts, then adjust the handles, after which a few turns of the nut will draw up the toe-bolts (handle-bolts) and firmly lock the handles in position.

The valve (Figs. 11, 12, and 13, Plate XIII.) comprises two air-driven piston-valves *l*, *m* (valve-plunger), whose end-portions work in single-acting cylinders *N O*, *N′ O′*, formed in the ends of the steam-chest *J*. The central portions of the pistons *L*, *M* are considerably reduced in size in order to allow of the free passage of steam or air around and between them to the main auxiliary set of ports 1, 2 located side by side

transversely to the central portion of the steam-chest, and both are of the same external dimensions so as to render the valves interchangeable if desired. For convenience in construction, the steam-chest consists of two parts: the valve-chest which contains the pistons *L*, *M* (valve-plungers), and the valve-seat in which the ports are formed. The pistons *L*, *M* are each provided with a slide-valve moving upon and controlling the two seats of the ports 1, 2.

One series of the ports comprises inlet-port *P*, exhaust-port *Q*, and inlet-port *R*. The port *P* communicates by passage *P'* with inlet-port *p*, located on the opposite side of the steam-chest, and extending into the cylinder *O*. The port *R* also passes across the steam-chest by passage *R'*, issuing at the outlet *r* into the cylinder *O'*. The exhaust-port *Q* extends laterally to the exterior, and adjustable throttling-valves, regulating-screws *q'*, *q''* are provided for increasing and diminishing the area of the exhaust-passages, and of the ports *P*, *R*, thereby controlling the speed of movement of the valve actuating-pistons (valve-plungers).

The second series of ports comprises *a*, *a'* leading to the respective ends of the main cylinder, and the exhaust-port *B*, leading to the exterior of the machine. From the port *a* extends an auxiliary passage 3, which crosses the steam-chest and issues at the opening 4 into the cylinder *N'*. From the port *a'* extends a similar passage 5, which likewise crosses the steam-chest, and issues at the opening 6 into the cylinder *N*. The valve-actuated passages just described are smaller than the main ports, being about one-third of their area.

When the valves are in position, the compressed air in the chest will find passage alternately through the ports and passages shown, which will cause them to move alternately and independently of the movement of the main piston, so long as air is supplied and the exhaust-port *B* is open. The passages cross each other without communicating, as shown in Fig. 11, each piston being alternately the valve of the opposite one, and their speed can be regulated by throttling the ports *P*, *R*, to a greater or less extent.

The specific operation of the valves in the position shown in Fig. 12 is as follows:—Piston *M* being in its forward position, the piston *L* will exhaust through the passage 5 and receive air at its opposite end through the passage 3. Simultaneously the piston *M* will receive steam through the passage *P*, and exhaust through the passage *R*, and so on as long as steam or air is supplied.

The Ingersoll-Sergeant machine has been used with highly satisfactory results in the different mines; first, for driving headings at the Dominion

No. 1 mine in the north deeps, whilst the Stanley header was working on the south side, and although, of course, the rate of progress in the initial stages was much slower, it was found as a matter of fact that the deeps were completed for a given distance just as quickly as on the south side, and at less cost. The reasons are obvious: the percussion-machine, not being confined in any rigid position, could be humoured to suit the varying conditions of work, and so handled as to avoid difficulties that hampered both the Stanley header and the longwall machines; *e.g.*, the water could be avoided by cutting a little higher up the face of the coal, and leaving a shallow bench to be afterwards wedged up; an irregularity or roll in the pavement could be negotiated in a similar manner; a stone or layer of pyrites could be cut around and dislodged; and then the greatest advantage of all—the road could be driven the full size from the commencement, and completed day by day.

The deeps were driven 12 feet wide and 7 feet high. The maximum rate of progress was 90 feet a week in each road, working three 8 hours' shifts; the average rate being about 80 feet. This speed would have been exceeded, but the wide heading in so thick a seam yielded a large tonnage, say 10 tons to the yard, and it was not possible to remove this quantity as rapidly as it could be cut and blasted. As fast as the deeps were driven down, rooms were broken off, and, by the time they had reached the present limit of 2,000 feet, working-places were ready from the top of the deep to the bottom. The same process was repeated on the south levels, affording at the end of one year from the commencement of driving to the deep of the shaft, 3,500 lineal feet of workings, 75 rooms, and an output of 1,000 tons per day; the whole being opened out and mined by the machinery which has already been described.

Mode of Operation.—The writer will now give an account of the method of handling and working percussion-machines, and the same description applies equally to the three varieties mentioned.

The machine, if the pavement be hard, can be dragged from room to room on its own wheels by means of a rope, and, if the grade does not exceed 1 to 12, two men can compass this. If, however, great expedition is required, or if there be a sufficient number of machines working in any one section, it is more economical to have them hauled round on a low truck by a pony; one pony and a boy will attend to twelve or fifteen machines. The machine, board, hose, and fittings can easily be packed together, on one small truck.

Under-cutting.—Each machine works on a flat board, 6 feet long by 3 feet wide, which should be substantially made of pine or other hard wood, 2 inches thick. This board is set endways to the face and the back-end is raised, so as to give the board a pitch towards the face of, say, 3 inches in the yard. The machine is then dragged on the board and a length of pliable hose connected from the nearest stationary air-pipe. The operator sits on the board at the rear of the machine, with one hand on each handle. He also, as a rule, wears an iron shoe over his left foot and places that behind the left wheel, leaving the right leg across the board. The air is then turned on, and the piston makes a stroke on the face of the coal, which causes the latter partially to give way and the machine partially to recoil, but its own weight and the sloping grade of the board carry it to the front again, and so the process goes on—the machine doing all the cutting, the man simply steering it. When the under-cutting is finished, the same machine can be used, if desired, for shearing; all that is necessary is to take off the ordinary wheels and put on a larger pair, proportioned to the height of the seam. In the 8 feet seam, it was found by using wheels 32 inches in diameter and a rather longer pick, that a clean shear could be made to the top.

Drilling.—Following this, the Jeffrey borer comes along in charge of two workmen, who with one drill do the boring for twenty rooms, that is, two holes in each room, each 5 feet deep. The actual time for boring each hole with one change of drill is two minutes; the rest of the time is consumed in moving the drill from room to room, and in setting up the machine.

Blasting.—The coal being undercut from rib to rib, and sheared in the centre, the two boreholes are put in as near the ribs as possible, and blasting follows. Often the coal comes down practically in two large blocks, with very little small, and then the work of cleavage is heavy, the rooms being from 20 to 22 feet wide. The coal is now ready for loading, and the writer need not follow the process further. There are, however, three important points on which he knows reliable information will be valuable to the members.

(1) *Proportion of Slack.*—An important question arises as to the proportion of slack made by the machines as compared with hand-labour. To illustrate this matter, the writer appends a sketch (Fig. 14, Plate XIII.) which shows in section the space cut away by each method in the same seam. This drawing is made from actual measurements and represents in each case a fair average result. It will be seen that there is a saving

of coal in favour of the machine of about 40 per cent., *i.e.*, the machine makes 40 per cent. less slack than hand-labour, and the reason is obvious: the workman requires more room underneath after the first cut to swing his arms and pick, than the machine to drive its cutter.

(2) *Quality of Coal.*—The machine has no effect on the quality of the coal produced, if ordinary intelligence and skill be used in directing it, and especially in taking the cut clean up to the rib, and making it a little deeper there than elsewhere, so that when the shot is fired, it will fall readily.

(3) *Amount of Work.*—In making an estimate of the amount of work performed as compared with that done by hand-labour, it is necessary to remember that the general arrangements are totally different for the two systems. In the case of the machine, the operator does nothing else but attend to his machine, and he has a helper to rake away his cuttings, and help him generally. This keeps the machine profitably employed all the time. In the case of hand pick-work, the workman performs all the processes of cutting, shearing, blasting, loading, and timbering. Confining the estimate, however, exclusively to the under-cutting, the writer finds that an average day's work for a hand pick-man is about 50 square feet, and for a percussion-machine about 200 square feet; although a good workman can under-cut 300 square feet, and in the special test referred to, the three runners averaged more than 500. These figures show the actual capacity of the machine, but in average working it is safe to assume that when once the workmen have become accustomed to the use of the machine, they can comfortably manage from 200 to 300 square feet.

The writer appends a statement showing the details of the result of the special test, which excited great interest, and established a record for this class of work.

TABLE I.—SHOWING THE AREAS OF COAL UNDER-CUT AT THE DOMINION No. 1 MINE, DURING THE SPECIAL TEST IN AUGUST, 1895.

Name of Machine.	Under-cut.	Full Days.	Cut. Per Day.	Hours Worked.	Cut. Per Hour.
	Sq. Feet.		Sq. Feet.		Sq. Feet.
Ingersoll-Sergeant ...	6,038	11	549	97	62·24
Yoch	5,929	11	539	99	59·88
Harrison	4,940	11	440	99	49·89
Totals	16,907	33	1,528	295	172·01
Average	5,635	11	509	98	57·30

(4) *Physical Effects.*—The question has often been asked, as to whether working with the machine is harder for the workman, and as a rule it has

been presupposed that the reply would be in the affirmative. The writer has, however, no hesitation in stating that after the first month the work is decidedly easier, being less exacting than hand pick-work, and as a matter of fact when workmen have once learned how to manage the machine they will not give them up on any account. When they were first introduced in Cape Breton, every one was opposed to them—not a workman would look at them. Experts had to be imported to start them, and instruct the workmen. That was two years ago; to-day there is not one expert left. There are now workmen who can cut more coal than the experts did when here. There are more applicants than machines, and last year the machines under-cut 226,000 tons. This statement marks considerable progress for so short a time, and speaks well for the popularity and efficiency of the machines.

Yoch Machine.

The writer has dealt at considerable length upon the construction, capacity, and method of working of the Ingersoll-Sergeant machine, because, as previously stated, it is fairly representative of the three machines of this type under consideration. There are, however, several special features about the Yoch machine (Fig. 15, Plate XIII.) which will repay attention, and which the writer would now like to point out. He may preface a detailed description of its construction by saying that the principal features are additional weight, larger cylinders, and the important factor that it cushions upon air instead of upon a leather buffer, as in the case of the other machines. This cushioning is effected by means of an escapement-valve, which allows a small quantity of the compressed air to reach the front of the cylinder in time to receive the piston. The advantages are considerable, as the air is elastic, and there is consequently less jar and vibration on the machine, to the advantage of the latter as well as of the workmen.

One of the first objections always raised to the Yoch machine is its additional weight, a matter of some 400 pounds greater than the Ingersoll-Sergeant or Harrison machine. This necessitates a horse for moving it round from room to room; but there are compensations: (*a*) although heavier it is just as easy to steer; (*b*) having larger cylinders, and being somewhat more compact, and altogether stronger in construction, it strikes a heavier blow; (*c*) it is, the writer is disposed to think, less liable to get out of order; and (*d*) there is less vibration.

When first introduced the workmen were opposed to it, and all were in favour of the smaller machines; but it is a singular fact that, during

the last season, after trying one or two of the Yoch machines, they became very popular, and in a little while the whole of them were asked for and placed in the hands of workmen who had previously been working the other machines. This favourable opinion bears out a remark which the writer made above, to the effect that although the Yoch machine looks heavy, and suggests at first sight a necessity for a burly, strong workman to handle and move it, as a matter of fact it is not so in practice. The machine and not the man does the work, and any ordinary miner can handle one. It is, of course, as true in connexion with coal-cutting as with anything else, other things being equal, that a big man is stronger than a little one; but speaking generally it is not true that a little man stands at any greater disadvantage in working a coal-cutting machine than in using a pick. In confirmation of this opinion, the writer may state that although the Harrison machine came out at the bottom of the list in the special test just referred to, this position was due entirely to a defect in the machine which was not discovered before the test began, but it has since been remedied. This machine was worked by a man who weighed less than 150 pounds, but who was able to cut an average of 440 square feet per day; and two workmen, who only learned to operate the machine in 1894, are the best cutters in the Dominion mines, and neither of them weighs over 160 pounds.

The Yoch mining machine is of heavy solid construction, the main cylinders being 24 inches long by 6 inches in diameter. The piston-head is made of grey cast-iron, four packing-rings are sprung on, closely fitting to the walls of the grooves cut in the head to receive them. The rings are cut, so as to allow them to expand outwardly and make air-tight joints between the bore of the cylinder and the periphery of the packing-rings; thereby preventing any leakage of air from one end of the cylinder to the other, and securing the full power of the air-pressure upon the area of the cylinder-bore. The piston-rod is $3\frac{1}{4}$ inches in diameter on the rounded portion, and $2\frac{1}{8}$ inches square on the guiding or square portion. It is fitted with an ordinary stuffing or packing-box and gland to ensure absolute prevention of leakage, and is easy of access for the insertion of packing. The rod has a range of stroke from zero to 16 inches, and can be instantaneously adjusted by means of the regulator to any length of stroke desired, within those limits, and that without changing the position of the throttle-valve.

The guiding-sleeve, or front-head of the cylinder, is 32 inches long, and is constructed in one piece, securely connected with the cylinder. This sleeve is cut longitudinally on opposite sides of the front-end to

receive cast-steel gibs, used for the purpose of holding the piston-rod in its true position in the centre of the bore of the cylinder, and the inside surface of the gibs coming in contact with the piston-rod is planed so as to act as a safe and reliable guide for the rod during its active operation, and to prevent any twisting tendency resulting from glancing blows on the surface or face of coal, which invariably occur. The sleeve, being slotted to receive the gibs, is bored out on the inside, and the outsides of the gibs are turned true, so as to fit the bore of sleeve, which is then held and clamped securely by means of four turned bolts.

This guiding gibs-system embracing the piston-rod for a length of 12 inches longitudinally, having a square bearing-surface to prevent the too frequent wear which is noticeable on other piston-rods, with only 3 to 4 inches in length of bearing on the gibs, is clearly noticeable, and this long bearing with variable stroke of piston is appreciated as a repair-saving quality.

The machine under discussion is also equipped with self-acting automatic air-cushions to prevent the piston-head from striking the ends of the cylinder. Two check-valves, placed in both ends of the cylinder, imprison the air in the cylinder so as to make a soft springy cushion. They require no attention in repairs, unless, perhaps, a small piece of coal or pyrites becomes lodged between the check-valve and its seat, thereby preventing the proper action of the valve. This defect is self-apparent, as the next blow will strike the cylinder-head, and warn the operator of the trouble. The saving in repairs caused by this feature in a machine of this kind makes it stand a step far in advance of its competitors.

The writer will now examine the valve motion of the machine, and trace the action of air after passing from the air-receiver to the valve, and thence to the piston of the main cylinder. The main valve is driven by a separate single-acting reciprocating-engine, and is of the class known as side-valves. On the back wing of this valve there is a hub, $1\frac{3}{4}$ inches high by $1\frac{1}{2}$ inches in diameter. On this hub is fitted a wing-valve, which works on the side of the air-chest, and acts as a cut-off valve between the air-receiver and the air or valve-chest. This cut-off valve is operated by a direct connexion to the piston-rod of the small reciprocating-engine, and is connected by a pitman-rod which drives the main crank; this crank has an eccentric key to it, and this operates the small-engine valve, thereby keeping up a continuous motion. The forward stroke of the small engine-piston propels the cut-off valve; this in its connexion carries along the slide-valve, and when the slide-valve is opening the cut-off takes place. It will be observed that the air-chest is charged with the

full air-pressure, and then cut off. The main valve then opens, and has got a sufficient supply of air to complete the stroke by expansion. This method of using the air is similar to that of measuring out each particle necessary to execute the labour required, and at the end of each completed stroke the terrible recoil which other machines of this class possess, is greatly reduced. It enables the operator to use more power (assisted by the weight of the machine, 1,200 pounds), at the start of the blow, utilizing the sudden speed attained by the piston, assisted also by the imprisoned air in the main cylinder, cushions, and is then cut off after having advanced seven-twelfths of stroke; the balance of work being performed by expansion.

It has been found expedient to use the full power of the machine in mining, and in order to be able to handle the same, without the recoil jarring the operator so severely as to call forth protest, and eventually condemn the tool, the inventor saw plainly that, instead of decreasing the power of the machine, it was necessary, by auxiliary mechanism, to control and use the full power, and overcome the inconvenience which recoil and jar would cause to the operator. Hence, he introduced a novel and useful feature: an air-brake which operates automatically upon the right-hand wheel of the machine. This brake applies itself to the wheel only on the outward movement of the piston, and is so accurately adjusted that it times itself to each blow of the pick upon the surface or work operated on. This brake is thoroughly reliable and exactly accomplishes its functions; it prevents side-glancing of the picks, and allows the operator to accurately guide the strokes of the piston.

Another novel feature with which Mr. Yoch is now equipping some new machines, is a double-acting piston-head; one plunger acts on the wheel, and another acts on a friction-shoe which trails under and in the rear of the main cylinder. This trail or platform-brake is used to assist the operator to steady the machine and correctly direct its blows, at any angle above or below a horizontal line. Those two points being automatically taken care of by the brake, it only remains for the runner to crowd on pressure and get the full working capacity out of the machine.

Another valuable appliance, which is to be found only on this machine, is the pressure-regulator. This is a very simple device which exerts a wonderful influence upon the action of the machine. It consists of a small dome-shaped casing in which are two spiral springs, one within the other, and made from $\frac{5}{16}$ and $\frac{3}{16}$ inch steel spring wire. These springs are placed on to a double-faced valve, which, when the springs are compressed, increase the opening between the hose and the

machine, admitting the necessary amount of air to keep up the power required by the operator, regardless of the pressure applied on the room or entry piping. The throttle-valve may be turned wide open, and this regulator-valve can be so adjusted as to make the piston travel fast or slow, or, if required, the action of the machine can be stopped by this useful piece of mechanism.

System of Working.

Having now given all the information which the writer thinks is necessary to enable the members to form a definite idea of these machines, he will refer briefly to the system which has been found most advantageous in conducting the various operations of mining in connexion with them. It is obvious that where a large sum of money has been expended in plant and machinery, one of the first essentials is to arrange the working so that the machines may be kept in operation during the whole of the time, and not kept lying idle while the operator discharges any other of the duties which are usually undertaken by a coal-cutter.

It has been found economical to divide the various processes among different workmen, and the arrangement works out as follows: the machine is operated by one man, who has a helper. The duties of the helpers are to assist in moving the machine from room to room, fixing it in position to commence work, and raking the slack from underneath the cutting as it is produced. When the undercut and shearing are completed, the next operation is boring; this can be readily managed by placing the Jeffrey drill in the hands of two workmen, and allotting them a sufficient number of rooms to fill their day. In practice we have found that they can manage about twenty rooms, or forty holes.

The next process is the blasting, and as this requires to be done by men who are both skilful and careful it has been found advantageous to engage some of the best miners and give them charge of this department, and of the timbering and general safety of the rooms.

The last operation, loading, is performed by cheaper labour, under the supervision of the previous gang of men.

The whole of the work is done by contract, and in this way it is found that the maximum tonnage and the best results are obtained.

Extra Supervision.—Of course, it will be obvious to the members that if the full advantage of mining coal in this manner is to be obtained special arrangements, such as those named, and constant supervision, will be necessary, as the tonnage of coal produced in a given district

is so much greater than by the old method. The increased production necessitates better organization and closer attention, especially in the manner of performing the various processes which follow the cutting of the coal. It also becomes increasingly important that the haulage-appliances should be of the best kind, as half the benefit of the system will be lost unless the coal be moved from the working-places as readily as it can be loaded.

For these reasons it will be manifest that the difficulties of installing such a system in a mine which has been operated perhaps for many years by hand-labour are considerably greater than when it is possible to lay out the mine from the commencement with this end in view. In the latter case nothing is easier, and the writer ventures to think that from this date forward very few large mines will be opened without keeping this factor well in view, as, unless we are to be left behind in the race of competition with all the foreign coal trade, we must adopt the same methods as our successful competitors, where these methods have been shown to cheapen production.

General Requirements.—The principal requirements to be borne in mind in opening any such mine are, efficient motive power, large pipe-ways, sufficient receivers, dry air, cooling appliances in the air-compressor house, and ample hauling-roads and airways. In the latter connexion it must not be forgotten (so long as blasting is resorted to) that in producing so much more coal over a given area a greater quantity of powder-smoke is given off, and larger airways are necessary.

Cost.

The writer has reserved until the last the consideration of a branch of this subject upon which he knows the members will be anxious to have some information, but which is the most difficult to deal with, namely, the question of cost. It is certain that experience in Cape Breton in this respect would be no guide to the cost in Great Britain, all the conditions being so totally different. For instance, the coal-seams are uniformly alike, being of considerable thickness, hard, with a rock roof, and a strong pavement. In this respect all the conditions are favourable to the use of mining machinery, more so than in the average British mine. On the other hand, owing to the severity of the climate and the freezing of the St. Lawrence river, the mines lie idle practically during four months in the year, and as a consequence the workmen must earn a larger daily wage in the shipping season than the average

miner in the old country, who works more or less all the year round. It would therefore be useless to quote our figures. The writer has, however, made a careful calculation, based upon his experience in the colony and his knowledge of the conditions of mining at home, and he believes that the following figures may be relied upon as giving a fairly accurate estimate of the cost of setting up and maintaining a coal-cutting plant, and of the various processes of mining under that system—if applied to an average seam in Great Britain.

For this purpose he will assume a strong coal-seam, 6 feet thick, with a good roof and hard floor, and will consider the same under two aspects. First, on the assumption that it is proposed to introduce coal-cutting machinery into a mine already being worked on the pillar-and-room system in one district which is required to yield 500 tons of coal per day. This would require from thirty-five to forty rooms, each 20 feet wide, or a corresponding length of working-face. The writer has found in practice that each machine is capable in such a seam of undercutting 50 tons per day; and, making allowance for delays, falls, and other hindrances, he allots three rooms to each machine.

In the case of a mine worked on the longwall system, the surface expense of plant and machinery would be in about the same proportion to the tonnage required. The figures in Tables II. and III. could therefore be used in this connexion, but for percussion-machines and room-fittings, substitute one Mitchell longwall machine for each 200 tons of coal worked per day, at a cost of £500 each.

TABLE II.—SHOWING THE COST OF INSTALLATION OF PLANT FOR AN OUTPUT OF 500 TONS PER DAY, WITH PERCUSSION-MACHINES.

1 Lancashire boiler of 150 horse-power, with fittings complete, and erected	£650
1 straight-line air-compressor, cylinders 16 and 24 inches in diameter, and 30 inches stroke, with pipes, fittings, and all appliances complete, and erected	2,000
Engine-house for air-compressor	300
Pipe-line from air-compressor to working-faces, estimated distance 1 mile, mains 8 inches and 4 inches in diameter ...	650
Small pipes, hose, fittings, etc., to 30 rooms	500
12 percussion-machines, with picks, etc., at £100 each, complete	1,200
Labour in laying pipe-lines, etc., not included in the above estimate	150
Total	£5,450

NOTE.—Ten per cent. should be added for contingencies.

The question of how this cost compares with the cost of a similar seam worked by hand is a matter which the author is unable to go into, but for purposes of comparison, he thinks that the above figures will be

TABLE III.—SHOWING THE COST OF INSTALLATION OF PLANT IN LAYING OUT A NEW MINE FROM THE COMMENCEMENT FOR AN OUTPUT OF 2,000 TONS PER DAY, WITH PERCUSSION-MACHINES.

3 Lancashire boilers, each of 150 horse-power, with fittings complete, and erected	£1,950
Boiler-house	300
2 compound air-compressors, cylinders 22 and 44 inches in diameter and 42 inches stroke, with pipes, cooling-appliances, water-tanks, fittings, etc., complete, and erected	8,000
Engine-house for air-compressor	600
Pipe-line, from air-compressor to working-faces, estimated distance 1 mile, mains 12, 8, and 4 inches in diameter ...	1,000
Small pipes, hose, fittings, etc., to 120 rooms	2,000
40 percussion-machines, with picks, etc., at £100 each, complete	4,000
Labour in laying pipe-lines, etc., not included in the above estimate	500
Total	£18,350

NOTE.—Ten per cent. should be added for contingencies.

TABLE IV.—SHOWING THE ESTIMATED COST PER TON OF MINING WITH PERCUSSION-MACHINES.

	s.	d.	s.	d.
Labour—				
Under-cutting	0	3		
Shearing	0	1		
Boring	0	0½		
Blasting, including cost of powder	0	1½		
Timbering, and special supervision	0	2		
Loading	0	4		
			1	0
Stores, etc.—				
Material, and other charges	0	1		
Machine supplies	0	2		
Proportion of motive power	0	1		
Depreciation of plant and machinery, and interest on outlay	0	1		
			0	5
Total			1	5

found reliable. He would, however, before leaving this matter, point out that whatever advantage may be derived from the use of percussion-machines in the ordinary working-places of the mine, there is no doubt whatever that they are of immense advantage in driving headings. The writer has referred to this at greater length at an earlier part of the paper, but he mentions it now so that due weight may be given to that fact in considering the question of cost.

The writer estimates that in such a coal-seam as is now under consideration, a heading 12 feet wide and 6 feet high, intended for a double

track for endless-rope haulage, can be driven in Great Britain for about 1s. 2d. per ton on the coal excavated, inclusive of yardage and tonnage, and a single road, say 6 feet wide and 6 feet high, for 1s. 6d. per ton on the coal excavated. This includes cutting, blasting, and filling only.

In making these estimates the writer is bearing in mind the average rate of wages earned by miners in Great Britain, and he is assuming that the same result would follow the introduction of this class of mining machinery as in the case of Cape Breton, namely, that the machine operators would expect to earn increased wages.

General Conclusions.

To summarize briefly the conclusions at which the author has arrived as the result of experimenting and working with the foregoing machines, he considers that it has been amply demonstrated :—

Advantages.—(1) That in consequence of keen competition, and the necessity for increasing to the maximum capacity the output of mines, some mechanical means for cutting coal must be adopted in the near future.

(2) That one or other of these machines can be used with advantage, both on the score of efficiency and economy, for the purpose of mining coal.

(3) That it is possible to introduce the system into any well regulated mine at present in operation, although it may not have been laid out originally with this intention.

(4) That it is practicable to work one district of a mine on this system without adopting it for the whole of the mine, and without interfering with the other districts, but it is not economical to do so, unless the whole of the district can be given up to it.

(5) That in the case of a new colliery just being opened, it is in the highest degree advisable, unless the conditions of the mine are exceedingly difficult (such as an abnormally bad roof, and soft wet floor) to make provision in the first instance for the introduction of mining machinery.

(6) That in the case of an exceptionally favourable mine with strong roof and floor, it would be the best policy to lay down the plant from the commencement with the view of working the whole of the output by machinery, and the larger the output required the greater the advantage of this system.

(7) That while there is an undoubted saving in the actual cost of production, this is not the only, nor indeed the most apparent advantage. The author considers that in the opening up of a new mine it would pay

to put down a small plant for the purpose of driving all the headings, even if it were taken out again, and not used for the ordinary mining of coal, so great is the saving which can be effected in the cost of this class of work, and also in the speed with which it can be performed. The writer has no data to guide him in this statement, but during an experience of more than twenty years, the opening up and development of a new mine to a capacity of 1,000 tons per day within a year is without parallel, and this was effected at the Dominion No. 1 mine. Such a result must be accredited entirely to the use of mining machines.

(8) A further advantage is the larger tonnage of coal which can be produced from a given area or length of working-face. This increase the writer estimates at double the production of hand-picks, and it is hard to calculate the extent of the saving in a large mine due to this fact. It means half the length of working-face, and probably not more than 75 per cent. of the roads and airways to be constructed and maintained for any given output.

(9) There is a further advantage of a very material character in the fact that a so much larger output of coal can be secured with the same number of men, and there are times when under sudden stress of demand this becomes a very important matter, as it enables one to respond more promptly, and without difficulty to a sudden demand, the elasticity of the system being much greater than is possible under the older method.

(10) The writer would also class with the advantages the fact that, whilst working at a price which is satisfactory to the employer, the machine-operator can earn considerably more money than by the hand-picks. This soon popularizes the machine, and makes contented workmen. It is also a move in the direction of all modern mechanical substitutes for arduous and unnecessary manual labour, which ought soon to be as obsolete in the mine as it is in a well-equipped modern iron and steel works.

Of course, some of these advantages are not so apparent in a densely populated country with surplus labour generally at hand ; but in a new country, or even in a new district, it would be impossible, within a short time, to collect a sufficient number of men to open up and develop a large mine. We all know, under such circumstances, the experience of collecting men together a few at a time, and making what appears to be snail-like progress, while capital is being expended, and the mine is eating its head off with interest ; and under any circumstances, if there be a justification for opening up a new mine, there must be at least equally sufficient reason for opening it up as quickly as possible.

Disadvantages.—(11) There are certain disadvantages that should be enumerated. Among these are the addition of a considerable sum to the capital outlay, and consequently the fact that in times of stagnation there is much more capital lying idle; the difficulty and opposition which has to be encountered in introducing a new method; and the necessity for conducting the general operations of the mine upon a different system.

It must also not be forgotten that mining by machinery entails in some respects a great deal of additional worry and anxiety upon the managing-staff. Nothing could be simpler than that a workman should carry his picks into the mine with him, or obtain them at some station, do his work, carry them out, and there is an end to the matter; but cutting by machinery means an almost daily lengthening of pipes in each working-place, the keeping of a large array of hose and fittings in working condition, the sharpening and supply of the picks for the machines, which, owing to the harder blow struck, are damaged or worn out much more quickly than a hand-pick; the supply of duplicate parts, and doing of constant necessary repairs to the machines themselves. All these details involve much labour and attention, and unless the staff be thoroughly well organized, and every detail carefully attended to, a satisfactory result cannot possibly be achieved. A successful result, however, as the members will observe, is entirely a matter of organization. There are no insuperable difficulties, and when once a mine has settled down to this system, it is quite possible to run along smoothly and efficiently; in the introduction of the method, however, much trouble lies.

Balancing the advantages with the disadvantages, the writer has no hesitation in saying that the former largely predominate.

The writer must apologize for the length of this paper, which can only be defended on the ground that, as he is residing at a distance of 8,000 miles from your meeting, it is perhaps justifiable to enter into the matter with more detail than would be necessary if he were present to read the paper, and take part in the discussion. The importance of the subject cannot be over-estimated. Like most Englishmen he had seen but little coal cut by machinery at home. At first he entertained all the prejudices which might be expected from an old countryman against a radically new system. After watching it carefully and handling it in all departments he is a convert, and does not hesitate to say to-day to his *confrères* at home that it is, he believes, the system of the near future. And that for many reasons, in addition to those which he has stated above, and which will become increasingly apparent and powerful as time progresses, the coal-mines of Great Britain

will be compelled before long very largely to abandon the primitive method of cutting coal by hand. Of course, these observations can have no reference to mines where, owing to the superincumbent pressure or texture of the seam, little or no under-cutting is required; but as long as headings have to be driven and strong seams of coal have to be undercut and sheared a machine will do this more efficiently and economically than a hand-pick.

The PRESIDENT said that some of the members in this district had coal-cutting machines at work, and he hoped that they would give the members the benefit of their knowledge of the subject. The seams worked in this district were very much thinner in section than those mentioned in the paper, and if machines could be more extensively used here, it might possibly reduce the cost entailed by the use of expensive hand labour.

Prof. H. LOUIS, referring to the Ingersoll-Sergeant machine, said there were two points on which he would like information. He understood the paper to describe the man in charge of the machine as having simply to attend to it, and reference was made to the day when there would be no more manual labour in reference to coal-cutting. He understood, however, from those who had worked them, that the manual labour necessary in using these machines was very considerable, and the workman had to exert very considerable strength to make the machine do effective work. It was necessary to sprag the machine with both hand and foot: with a chisel cutting 200 blows a minute that in itself required a good deal of exertion, and the men who worked these machines asked a high rate of wages. In another place the writer mentioned that there was more wear-and-tear on the chisels in the Ingersoll-Sergeant machine than on the pick in hand-cutting. This was exactly the reverse of what took place with the ordinary percussion rock-drill, with which when cutting hard rock less than half the wear of ordinary machine drill-chisels was experienced, and it would be interesting to have an explanation of the difference.

Mr. M. WALTON BROWN said that it was stated in the paper that the wages were higher for machine than for hand-pick work.

Fig. 8.

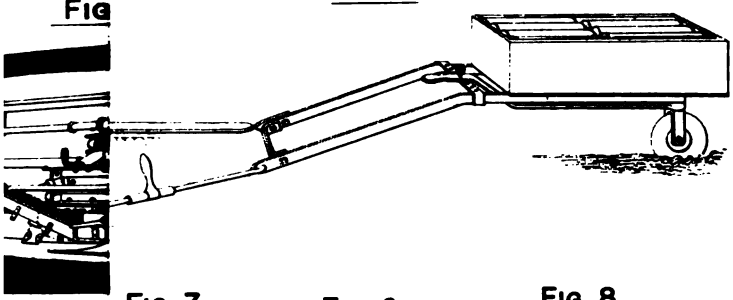


Fig.

Fig. 7.

Fig. 6.

Fig. 8.

Fig. 9.

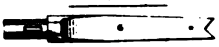


Fig.

Fig. 5.

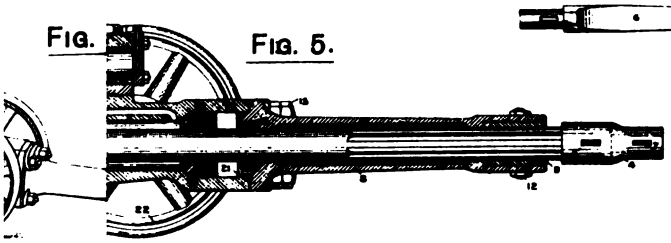
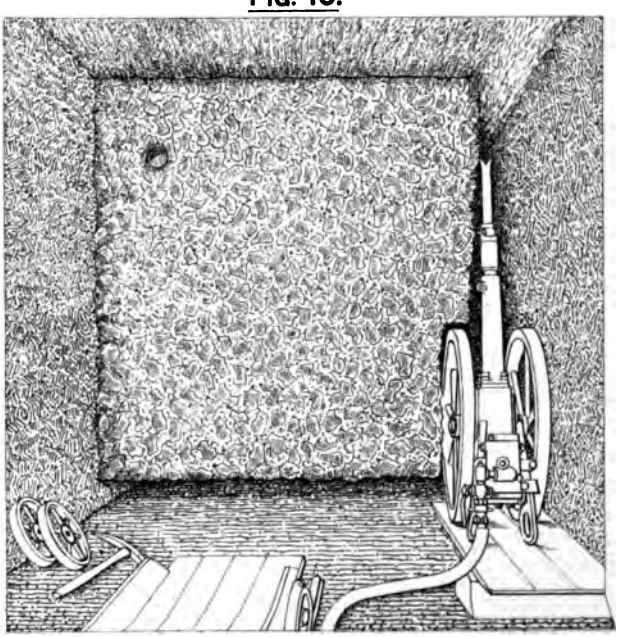


Fig. 10.



Prof. H. Louis said that in the province to which the paper referred, men working ordinary hand-picking could get 1,200 tons per annum per man, so that some reliable statistics on the matter were desirable.

Mr. William Blakemore, replying to the observations of Prof. Louis, explained that his remark as to the man in charge of the machine having simply to attend to it, applied to the Mitchell longwall, and not to the Ingersoll machine, as a reference to the text of the paper would show. Prof. Louis was quite right in stating that considerable manual labour was required in handling percussion-machines, and the paper explains that both hand and foot are used. But the writer still adheres to his opinion, based upon the employment of upwards of 70 of these machines, that the exertion is no greater than in the case of hand-picks. There are several reasons for this—the attitude is less constrained, and with the employment of skill the exertion is less continuous, as the machine can be made to do much of the work itself, and in the case of a hand-pick every blow of the pick must be wielded by the arm. The reason that men can command higher wages is obvious, namely, that they produce so much more coal.

It is a fact that the wear-and-tear of the chisels is much greater in the case of the machines than by hand-cutting; but the damage to the pick is caused more by foreign substances in the coal than by concussion with the coal. As many as 60 machine-picks have been used in coal-holing in a single shift, but this was under exceptional circumstances. The average number allotted to each workman is 12, whereas 4 to 6 hand-picks will suffice for a day's work.

The number of tons per annum cut by hand-pick and by machine varies very much in different districts, but to give Prof. Louis reliable figures, the writer may quote from the last pay roll at the mine under consideration, namely, for the week (5 days' work) ending May 15th, 1896, when 13 machines produced 2,943 tons of coal, an average of 226 tons each for the week, or 904 tons for the month. Assuming 8 working months to the year in this district, we get 7,232 tons per machine, which is six times that produced by a hand-pick man. In actual practice these figures will be exceeded, as at the time of writing men have not settled down to their average summer's work.

With reference to the President's remark that the average coal-seam in England was much thinner than the one under consideration, the writer admits this, but would point out that the thinner the seam the greater the advantage of the machine, speaking relatively, since the excavation required in the process of under-cutting is less than by hand-pick.

On the motion of the PRESIDENT, a vote of thanks was accorded to the writer of the paper, and the discussion was adjourned.

The SECRETARY read the following paper on "A Compound Winding-engine," by Mr. W. Galloway :—

A COMPOUND WINDING-ENGINE.

By W. GALLOWAY.

The compound winding-engine, which is now to be described, was erected about eighteen months ago by Messrs. John Fowler & Co., Leeds, Limited, at Llanbradach colliery, near Cardiff. The specification was prepared by the writer, who is therefore responsible for the general design, and for the dimensions of the principal elements of the engine. The writer intended to provide each of the four cylinders with a piston-valve, but agreed, while discussing the details with the engine-builders, to use piston-valves for the high-pressure cylinders, and slide-valves for the low-pressure cylinders. The available boiler pressure is 150 lbs. per square inch. The object aimed at in designing this winding-engine was to raise a useful load of 4 tons from a depth of 1,500 feet in 30 seconds with the aid of a balance-rope under the cages.

The drawings attached to this paper (Plate XIV.) are sufficiently explicit not to require any special explanation. The following are the leading dimensions, weights, and so on :—

Cylindrical drum, 17 feet in diameter and 8 feet wide; stroke of piston, 54 inches; cylinders, high-pressure, 24 inches in diameter, low-pressure, 44 inches in diameter; weight of cages, 3 tons 1 cwt. each. Two tubs in each cage, weight of each tub 12½ cwts., capacity of each tub, 2 tons of coal; weight of safety-hooks, adjusting-screws, and chains, about 7 cwts. for each cage. Winding rope (locked-coil) 1¼ inches in diameter, breaking strain 97 tons, weight 12½ lbs. per yard.

The speed of winding is controlled by an automatic expansion-valve working inside each piston-valve of the high-pressure cylinders, and regulated by a ball governor designed by the engine-builders.

Owing to the peculiar position of the colliery on the steep slope of a hillside, the winding-engine stands at a height of about 45 feet above the mouth of the shaft.

The engineman stands on a platform directly behind and above the level of the drum, and looks down upon the top of the pit. On this platform, the reversing-engine, the levers of the steam stop-valve, the blow-off cocks, and the steam-brake, and the treadle of the foot-brake are

grouped together in convenient positions. The winding-indicator is directly opposite to, about 15 feet distant from, and on the same level as the engineman.

In considering the question of starting and stopping a compound engine, it had occurred to the writer, as long ago as the year 1886, that the simplest method of accomplishing this object was to convey steam through a small special pipe extending from the engine-side of the steam stop-valve to the intermediate pipe between the high and low-pressure cylinders, and to interrupt the free passage of steam through this special pipe by means of a reducing-valve adjusted to a rather lower pressure than that obtaining in the valve-chest of the low-pressure cylinders. In 1887, the writer erected a small compound winding-engine, fitted with this arrangement, which worked with perfect success for over two years.* The same arrangement has been adopted in the large compound winding-engine. *E* is the steam stop-valve, *F* the high-pressure steam-pipe, *G G* are the special pipes, *H H* the reducing-valves, and *K K* the intermediate pipes (Figs. 1 and 2, Plate XIV.).

In the absence of the balance-rope, it is found that the winding-engine does not start with sufficient rapidity unless the reducing-valves are set so as to give a pressure of 50 or 60 lbs. in the intermediate pipes, when the steam stop-valve is wide open. But this pressure is considerably greater than the mean working-pressure in the low-pressure cylinders ; as a consequence, there is a continuous flow of steam through the reducing-valves, and, so far as that steam is concerned, the benefits derivable from expansion are lost. On the other hand, the automatic expansion-valves come into action at the fifth or sixth stroke of the winding-engine, thus reducing the amount of work done in the high-pressure cylinders, while maintaining a difference of pressure between the steam in the high-pressure pipe and the intermediate pipes of 70 or 80 lbs., and the flow of steam through the reducing-valves continues during the whole operation of a winding.

In order to obtain the full benefits of expansion by causing the whole of the steam to pass through the high-pressure cylinders, either the work to be done by the winding-engine must be decreased by adding the balance-rope as at first intended ; or by reducing the useful load ; or, by removing the automatic expansion-valves while retaining the maximum useful load, and giving the engineman the means of closing the special pipes as soon as the engine has arrived at its maximum speed. Of the three proposals the first is undoubtedly the best.

* *Proceedings of the South Wales Institute of Engineers*, vol. xvi., page 111.

Continuous indicator-diagrams were taken at a time when the engine was working without the balance-rope, and with the expansion-valves. The writer has not since then had an opportunity of altering the engine in one or other of the directions suggested above; but he ventures to submit the results in their present form, in the hope that other members may be induced to contribute similar information in connexion with winding-engines, so that a comparison of results may be possible.

The indicator-diagrams were necessarily taken one after the other, as only one continuous indicator was available, and the conditions were made as much alike as possible. It was not practicable, however, to keep the boiler-pressure quite uniform, on account of the many other demands for steam, and as a matter of fact the pressure varied from 110 lbs. to 145 lbs. per square inch during the trials.

The same useful load of 3 tons 3½ cwts. was kept in one of the cages, which was raised to the surface while each indicator-diagram was being taken and then lowered back to the starting-point at a depth of 1,506 feet. When the boiler-pressure was 130 lbs. per square inch and upwards, the time occupied in a winding was 45 seconds, and when it fell to 110 lbs., the time occupied was 64 seconds.

The unbalanced weight of rope hanging in the shaft when the cage was at the bottom was 6,275 lbs., and the work done in raising it to the point where the cages met was consequently equal to one-half of that weight raised one-half of the depth of the shaft.

The results deducible from the indicator-diagrams are unfavourable to the engine. For instance, two of the indicator-diagrams of the low-pressure cylinders show that the boiler-pressure was not high enough to enable the high-pressure cylinders to do their part of the work, and, as a consequence, a large amount of steam passed through the reducing-valves to assist the low-pressure cylinders.

The calculated number of strokes of the engine is 28 for each winding. It will be seen that the normal number of strokes made under steam was 15, and that the momentum then acquired was sufficient not only to complete the work, but that in every case air was drawn into the low-pressure cylinders and compressed, while in two cases the engine was apparently reversed to a small extent and steam admitted to the high-pressure cylinders, so as to bring the engine to a standstill at the proper point. The steam-brake was not used, and the foot-brake was only used at the last moment when required to slightly retard the upward velocity, and to modify the blow when the cage settled on to the keps.

In calculating the weights of steam, no account has been taken of the diagrams produced by compression, because although a small quantity of steam may be wasted in this way, it has nothing to do with the effective work of the engine, and it could be easily avoided by the use of a balance-rope, which would both accelerate the velocity at starting and retard it at stopping. Each diagram representing one stroke of each piston was measured separately by the planimeter, so as to ascertain the mean pressure, and the corresponding weight of steam at absolute pressure was ascertained from one of the tables constructed for the purpose. No account was taken of steam condensed in the cylinders or in the jackets of the high-pressure cylinders, so that the record is, in this respect, incomplete.

Taking the indicator-diagrams in descending order, the calculated weights of steam added together are as follows :—

No. of Diagram.	High-pressure Cylinders. Lbs.	No. of Diagram.	Low-pressure Cylinders. Lbs.
1A ...	50·832	1B ...	81·867
2A ...	44·788	2B ...	66·977
3A ...	52·638	3B ...	132·638
4A ...	49·119	4B ...	74·808
Totals ...	197·377	...	356·290

All the steam, except what is lost by condensation in the high-pressure cylinders, ought to reappear in the low-pressure cylinders. But on deducting the weight found in the former from that found in the latter, we find an increase of 158·813 lbs., which can only be accounted for on the supposition that it passed through the reducing-valves. If, however, we eliminate indicator-diagram 3B, which is abnormally high, probably in consequence of the low steam-pressure in the boiler (110 lbs.) at the time it was taken, and compare $\frac{4}{3}$ (1B + 2B + 3B) with the sum of (1A + 2A + 3A + 4A) the following results are obtained :—

	Steam Used. Lbs.
High-pressure cylinders	197·377
Low-pressure ,, ...	298·204
Difference	100·827

Even in this case, however, over one-third of the advantage is lost that would be obtainable from expansion if the load were reduced by a balance-rope or otherwise, and the reducing-valves were set to allow steam to pass only up to a pressure of 25 or 30 lbs. per square inch.

The actual work done by the engine in 45 seconds was thus :—

$$\frac{4}{3} \cdot \frac{7{,}112 \times 1{,}506 + 3{,}095 \times 753}{33{,}000} = 526 \text{ horse-power.}$$

Taking the consumption of steam as shown by the indicator-diagrams of the low-pressure cylinders (with the correction already mentioned) to have been in round numbers 300 lbs. for each wind, we get 17·07 lbs. of steam per ton of useful load raised 300 feet, and 51·9 lbs. per actual horse-power-hour.

Another winding-engine at the same colliery (with cylinders each 24 inches in diameter by 4 feet stroke, drum 14 feet in diameter, winding from a depth of 792 feet, useful load 5,180 lbs., unbalanced rope 2,114 lbs., time of a winding 25 seconds, weight of steam used per winding 108·225 lbs.) consumed 17·7 lbs. of steam per ton of useful load raised 300 feet, or 52·2 lbs. per actual horse-power-hour.

Consequently there has been no particular advantage gained so far by the adoption of the compound winding-engine, but on the other hand there has been no loss, notwithstanding the unfavourable conditions under which the engine is working, and the writer is satisfied that when it is completed as designed at the first, and provided with a balance-rope below the cages, it will give results, as regards economy in the consumption of steam, which will considerably surpass those obtainable from any simple winding-engine.

The drum of this engine was made as light as was thought consistent with its necessary rigidity. The bosses are of cast-iron, the spokes of channel-steel ; the H-girders which support the cleading are of steel ; the cleading, the flanges, and the brake-paths are of steel plates. The spare part of each winding-rope, 150 feet long, is coiled on a cast-steel reel inside the drum and concentric with it. The reels are fixed to the drum by means of bolts, but can be quickly unfixed and turned by hand. The ropes pass through two cast-steel pipes with easy bends, one close to each flange, and each rope is held fast by means of a strong gland, bolted to one of the spokes. This arrangement facilitates lengthening the ropes when they are recapped, and saves time in the operation.

Reversing is effected by means of a Melling reversing-engine, by means of which the motions of the winding-engine can be regulated with the greatest imaginable ease and precision.*

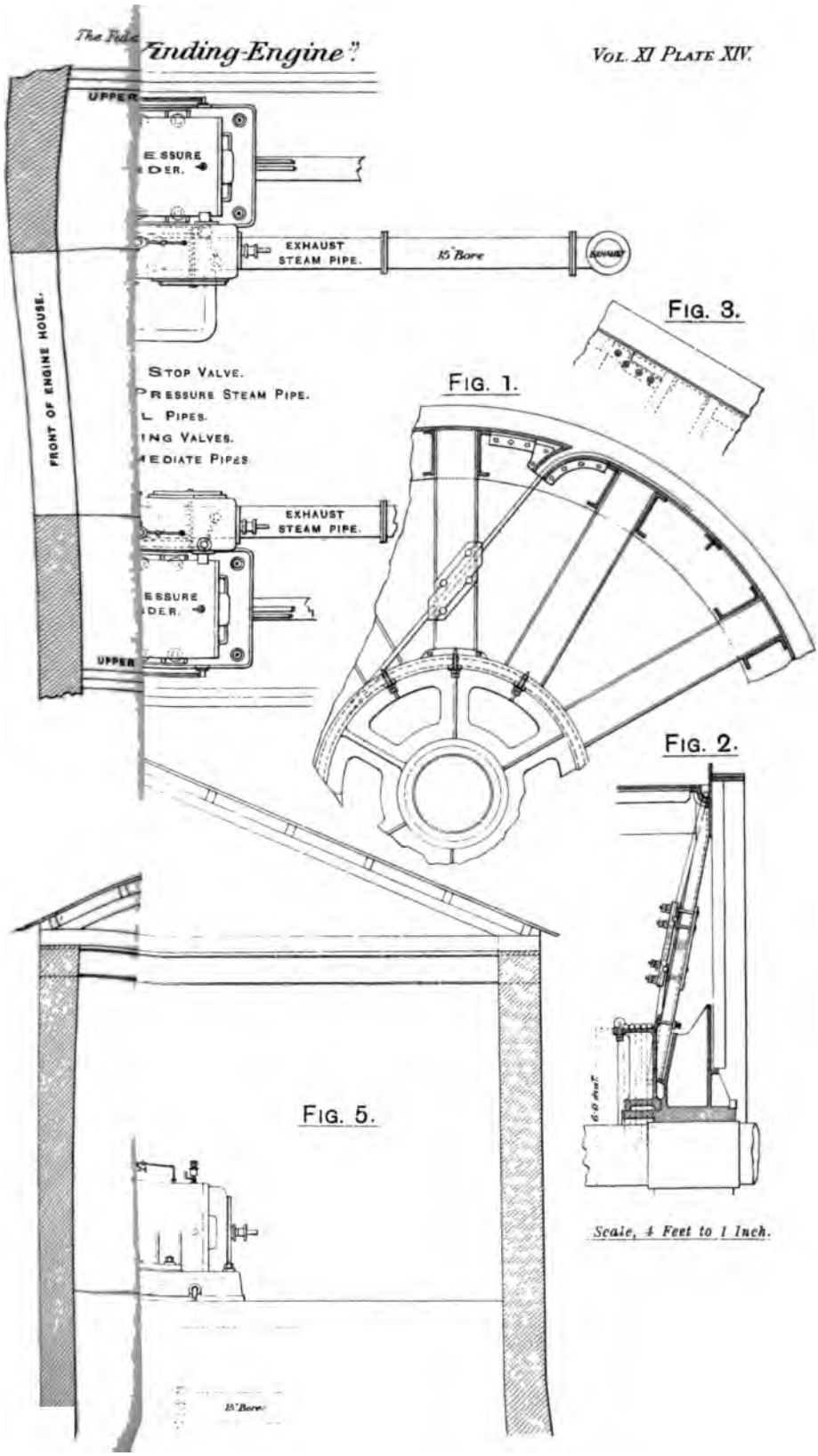
The steam stop-valve consists of two equilibrium-valves, a smaller one resting on a larger one. The smaller valve is opened first by the action of the stop-valve lever, and the larger one afterwards when the pressure upon it has been relieved to some extent.

* *Trans. Fed. Inst.*, vol. vii., page 370.

In conclusion, the writer should add that the work of measuring the indicator-diagrams and making the calculations were carried out by his assistant, Mr. Percy Lenderyou, and his pupil, Mr. Harold Clayton, and that both gentlemen, as well as Mr. J. R. Glass, the mechanical engineer of the colliery, rendered him every assistance in taking the diagrams.

Mr. J. A. G. Ross said that, as might have been expected, Mr. Galloway seemed to have found great difficulty in starting the compound winding-engine, and to overcome that difficulty he passed live steam into the low-pressure cylinder, which seemed a lame way of effecting economy, and to such an extent that he used 158 lbs. of live steam which escaped from the reducing-valve into the low-pressure cylinder. This seemed to be a defective method, and could not result in anything else but loss. With regard to Mr. Galloway's comparison of this engine with others, there was no basis of comparison, because they did not know precisely what it was doing, but it would seem on the whole that the system of compounding as applied to winding purposes was a failure. The quantity of steam employed seemed to be excessive—51 lbs. per horse-power.

Mr. A. L. Steavenson said that speaking from the point of view of one who used the machines, the first thing to be aimed at was simplicity; they wanted something that would not go wrong, that was readily handled, and could be worked to ½ inch at any point in the shaft. If the engine was not thoroughly under control, no economy would warrant the expenditure on a compound-engine. How many of them still had old-fashioned boilers, without covering, and steam-pipes, also without covering? They were losing more heat than could be gained by any compound-engine, and he thought that this was one of the first things to which they should attend. The utilization of 52 lbs. of steam per horse-power per hour was referred to in the paper, but the last statement he had seen applied to a Corliss engine, and that was 12½ lbs. of steam per horse-power per hour. He was not aware that there was another winding-engine in the country using 52 lbs. of steam per horse-power. Mr. Galloway had introduced a cylindrical drum with counter-balance-rope, but he (Mr. Steavenson) would prefer the scroll-drum. Do not let them discourage the introduction of better engines, if possible, but let them keep other things right as well.


UPPER
ESSURE
DER.
EXHAUST
STEAM PIPE.
15" Bore
FRONT OF ENGINE HOUSE.
STOP VALVE.
PRESSURE STEAM PIPE.
L PIPES.
ING VALVES.
EDIATE PIPES
EXHAUST
STEAM PIPE.
ESSURE
DER.
UPPER
FIG. 3.
FIG. 1.
FIG. 2.
FIG. 5.
15" Bore.
Scale, 4 Feet to 1 Inch.

Mr. W. GALLOWAY (Cardiff), in reply to the discussion, wrote that he had anticipated the difficulty of starting the compound winding-engine by providing it with reducing-valves from the outset. The reducing-valves act with perfect precision and with satisfactory results. The engine is, however, too small for its work, and will remain so until the balance-rope is added. When that is done, the writer had no doubt that the expected economy of steam will be attained altogether apart from, and in addition to, the economy due to the use of the balance-rope. The engine is under perfect control.

In his *Lectures on Mining*, Prof. Callon makes the following statement:—

> We may suppose that even with the employment of expansion and condensation the consumption of coal will amount to 11 lbs. (5 kilogrammes) per horse-power per hour (much more than this is consumed by most winding-engines), in consequence of the intermittent nature of the work, the irregularity of the resistance, and the frequently inferior quality of the coal supplied, at collieries at any rate.*

Eleven lbs. of coal evaporating only 6 lbs. of water per lb. of coal amounts to 66 lbs. of steam per indicated horse-power per hour.

Since writing the paper, the writer has received the following communication from Mr. Waymel, one of the engineers who lately carried out the sinking of the Vicq pits of the Anzin collieries by the Poetsch method:—

> Le diagramme continu donné par l'un des cylindres de la machine d'extraction de la fosse La Grange, le poids de vapeur par tonne élevé á 100 mètres est en moyenne, en tenant compte des pertes de toute nature, de 15 kilogrammes (per tonne utile).†

We have therefore 746,398·4 foot-pounds for 33·069 lbs. of steam, and 746,398·4 foot-pounds : 1,980,090 = 33·069 lbs. of steam : 87·7 lbs. of steam per horse-power per hour.

The winding-engine at the La Grange pit is of the most modern type, the ropes are balanced, being flat, of hemp, and working on reels.

The use of compound winding-engines appears to be receiving attention on the Continent. Mr. Berne, in a recent paper‡ on the employment of cut-off gear on the winding-engine of No. 2 pit of the Treuil collieries, belonging to the Société anonyme des Houillères de Saint-Étienne, gives the following data:—Diameter of cylinders, 39·37 inches; stroke of piston, 62·99 inches; area of piston, back end, 8·455 square feet; front end, 8·264 square feet; number of strokes, 42 per winding. There are three decks in each cage and two tubs on each deck. The useful load is

* Vol. ii., page 231. † A tonne = 2,275·95 lbs.; a metre = 3·2808 feet.

‡ *Bulletin de la Société de l'Industrie Minérale*, 1896, vol. x., page 61.

7,120 lbs.; the weight of empty tubs 2,976 lbs.; and the weight of the cage 7,275 lbs. The weight of the rope is 26·521 lbs. per yard. There are two hanging-on places for coal, one at 1,627 feet, the other at 2,034 feet. In winding coal, four tubs are usually put into the cage at the bottom; the cage is then wound up to the intermediate landing, where two tubs are added, and it is then raised to the surface. The water is all raised from the bottom in water-tanks, containing 836·34 gallons each. The initial diameter of the drum is 9·64 feet, and its final diameter is 21·2 feet. The weights are sensibly balanced, but the effort required at the end of a winding is rather greater than at the beginning. The water evaporated and the coal consumed during a certain period of time were both carefully noted, but he (Mr. Galloway) must refer the reader to the original paper for an account of the results. On the other hand, special trials were made with the engine while continuous indicator-diagrams were being taken, and he (Mr. Galloway) proposed to compare the results obtained with those given in his paper. Some of these diagrams were taken with the cut-off gear in operation, and others without it; some while coal was being raised, and others while water was being drawn.

It would lengthen these notes unnecessarily to give the whole of the figures in the original paper, so that he would confine himself to those that are essential:—

No. 1 diagram was taken with the cut-off gear in use, two full tubs being drawn from the bottom and four from the intermediate hanging-on place. The average pressure of steam was 19·31 lbs. In this and in the following calculations he took 14·7 lbs. per square inch as the pressure of one atmosphere. The weight of steam was 0·08358 lb. per cubic foot, 7,368·65 cubic feet was swept through by the piston, and the total weight of steam consumed was 615·87 lbs. The useful work done was:—12,592,363 foot-pounds, or 20,446 foot-pounds per lb. of steam, or 96·8 lbs. of steam per horse-power per hour.

No. 3 diagram was taken with the cut-off gear in use while winding water from the bottom. The average pressure of steam was 24·415 lbs., the weight of steam being 0·0951 lb. per cubic foot; the total weight of steam consumed was 700·74 lbs. The useful work done was:—17,040,948 foot-pounds, or 24,319 foot-pounds per lb. of steam, or 81·4 lbs. of steam per horse-power per hour.

The meeting then terminated.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 13TH, 1896.

MR. T. W. BENSON, VICE-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on May 30th, and that day.

The proceedings of the Council of The Federated Institution of Mining Engineers were reported.

The SECRETARY read the Balloting List, as prepared by the Council, for the election of Officers for the year 1896-97.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. OAKELEY ARCHER, Civil and Consulting Engineer, etc., 156, Hereford Street, Christchurch, New Zealand.

Mr. FRANK HERBERT BACKHOUSE, Manager and Mining Engineer, Coolgardie, Western Australia.

Mr. BRANDON TALFOURD BRIERLEY, Civil Engineer, 10, Marsden Street, Manchester.

Mr. THOMAS ROBERT DODD, Mining Engineer, P.O. Box 818, Johannesburg, Transvaal.

Mr. ALFRED FELLOWS, General Manager, The Bede Metal and Chemical Company, Limited, Hebburn, Newcastle-upon-Tyne.

Mr. WILLIAM GILL, Manager, Orconera Iron Ore Company, Limited, Apartado 42, Bilbao, Spain.

Mr. JAMES GRUNDY, Inspector of Mines in India, 27, Chowringhee Road, Calcutta, India.

Mr. Charles Hoffmann, General Manager, Geldenhuis Estate and Gold Mining Company, Limited, per Private Bag, P.O. Box 1022, Johannesburg, Transvaal.

Mr. John House, Colliery Manager, Rose Bridge and Douglas Bank Collieries Company, Limited, Wigan.

Mr. R. L. Hutchinson, Mining Engineer, 83, Howard Street, North Shields.

Mr. John William Jobling, Colliery Manager, Clifton Cottage, Burnley, Lancashire.

Mr. Julian A. Kebler, Second Vice-President and General Manager, The Colorado Fuel and Iron Company, Boston Building, Denver, Colorado, U.S.A.

Mr. George Appleby Bartram Miller, Colliery Manager, Bewley Road, Bedminster, Bristol.

Mr. Willard S. Morse, Mining Engineer and Metallurgist, Hacienda de Guadalupe, Huantla, Estado de Morelos, Republica Mexicana.

Mr. Arthur Richards, Consulting Mining Engineer, 65, New Broad Street, London.

Mr. Anthony Maurice Robeson, Mechanical Engineer, De Beers Consolidated Mines, Limited, Kimberley, South Africa.

Mr. John M. Rogers, Mining and Mechanical Engineer, Mount Hawke, St. Agnes, Cornwall.

Mr. William Henry Rowe, Mine Manager, 9, Earl Terrace, Douglas, Isle of Man.

Mr. Archibald Balfour Scandrett, Licensed Surveyor, Civil and Mining Engineer, Coolgardie, Western Australia.

Mr. Arthur Stone, Mining Engineer, Heath Villas, Hindley, Wigan.

Mr. William Watts, Waterworks Engineer, Oldham Corporation, Piethorn, near Rochdale.

Mr. Robert Williams, Mining Engineer, 30, Clement's Lane, Lombard Street, London, E.C.

Associate Members—

Mr. Edward Trenholm Bailey, Mining Engineer, c/o Messrs. Henderson and Macgeorge, Coolgardie, Western Australia.

Mr. John Bree, Estate Agent, The Homestall, Barley, Royston, Cambridgeshire.

Mr. E. Davenport Cleland, Bayley Street, Coolgardie, Western Australia.

Mr. J. W. Harrison, P.O. Box 2118, Johannesburg, Transvaal.

Dr. J. Loevy, Analytical and Metallurgical Chemist, P.O. Box 778, Johannesburg, Transvaal.

Mr. Cecil E. Northcott, Assayer, 57, Chancery Lane, London, W.C.

Mr. R. Henry Walcott, Technological Museum, Melbourne, Australia.

Mr. Richard Williams, The Johnson's Reef Gold Mines Company, California Gulley, Bendigo, Australia.

Associate—

Mr. Edward Elves, Back Overman, Middridge Colliery, Heighington, R.S.O.

Student—

Mr. George Dixon, Mining Student, Trimdon Grange.

PRESENTATION TO MR. A. C. KAYLL.

Mr. A. L. STEAVENSON (Durham) said that Mr. Kayll, for over five years, had given his time to the work of the Explosives Committee, and, in addition, had drafted and prepared a *Report*,* the value of which would be acknowledged by mining engineers in all parts of the world; and one feature of its value would be that it would remain with Mr. Kayll as a useful memorial of his life. As a token of their appreciation of Mr. Kayll's services, the Institute had arranged to make him a presentation of a gold watch and chain, and a valuable cheque. He had much pleasure on behalf of the Institute in asking Mr. Kayll to accept them, and trusted that they would remain with him all his life, and be a memorial that the members had not overlooked his most valuable services.

Mr. J. L. HEDLEY (H.M. Inspector of Mines, Newcastle-upon-Tyne) remarked that this presentation was in no way commensurate with the amount of time and labour which had been given by Mr. Kayll to the *Report*. The members of the Committee had met at Hebburn perhaps one day a week; Mr. Kayll had not only done this, but had gone down on various other occasions, and had also devoted a considerable amount of thought and time in furtherance of the experiments that had been made at Hebburn. The members of the Committee fully appreciated the work that Mr. Kayll had accomplished, and he was very pleased indeed to see that the work had also been approved by the members of the Institute.

Mr. A. C. KAYLL, in accepting the presentation, said he need scarcely remark that he was very much obliged to Mr. Steavenson and Mr. Hedley for their complimentary remarks. He had been assured by the Secretary (Mr. M. Walton Brown) at the commencement of the experiments that all services rendered were entirely gratuitous, and that the proceedings would only extend from three to six months, instead of which they had lasted about five years, so that the members would recognize that the experiments of the Explosives Committee had occupied a large amount of his time, and, in addition, he had also devoted much time to the study of the subject. He would take this opportunity of thanking every individual member of the Explosives Committee for their assistance during the course of the experiments. The thanks of the members were due to Mr. F. S. Panton, who drafted the specification of the apparatus, and superintended its erection. Mr. R. T. Swallow and

* *Report of the Proceedings of the Flameless Explosives Committee.*

Mr. Henry Ayton, on behalf of the Hebburn Coal Company, had afforded the Committee every assistance. He should also like to thank Mr. M. Walton Brown for the assistance that he had given him in the preparation and revision of the *Report;* at first he did not understand it to be his duty to prepare the *Report*, and he was quite certain that it would never have been written had it not been for Mr. Walton Brown's assistance. Finally, he wished to recognize the services and assistance which he had received from his colleague, Mr. J. L. Hedley, during the progress of the experiments. The thanks of the members of the Institute and of the Coal Trade were especially due to Mr. Hedley for the diligence and perseverance with which he had conducted the experiments to a satisfactory conclusion.

He did not assume for a moment that the Explosives Committee had exhausted the subject, they had merely been able to add a little knowledge to what was already known. The existing safety mining-explosives, although a great improvement upon those employed in the past, were not perfect, and it was only by further experiments that they would be improved. He hoped that the Institute with the Coal Trade would be able to make further experiments with mining explosives. In conclusion, he could only add that he felt very much complimented by the presentation, and was very glad indeed to receive it.

DISCUSSION UPON THE "REPORT OF THE PROCEEDINGS OF THE EXPLOSIVES COMMITTEE."*

Mr. W. N. Atkinson (H.M. Inspector of Mines, Newcastle-under-Lyme) wrote that the thanks of all interested in coal-mining were due to the members of the Flameless Explosives Committee for the great amount of trouble and time which they had devoted to the experiments on explosives, and the care with which the results are tabulated in the *Report.* They had proved their own title to be a misnomer, and that so far there is no flameless explosive. Nevertheless, the experiments demonstrate that there are now several explosives very much safer for use in coal-mines than blasting-powder, dynamite, and other explosives which, until recently, were alone available. It is very properly insisted on in the *Report* that none of the explosives tested afford complete immunity from

* *Trans. Fed. Inst.*, vol. viii., pages 227 and 593; vol. ix., pages 115, 206, and 274; vol. x., pages 38, 197, 492, and 503; and vol. xi., page 175.

ignition of fire-damp or coal-dust, and that the same precautions should be taken in their use as with blasting-powder; but the *Report* does not emphasize to the extent warranted by the experiments the greatly increased safety afforded by several of the explosives tested. When it is considered that in the experiments with stemmed shots fired into various explosive mixtures of fire-damp and coal-dust only 2 ignitions (of coal-dust) are recorded from 324* shots, and that if equivalent charges of blasting-powder had been used under the same conditions the result would doubtless have been an ignition in almost every case; it appears that something more might have been said than that the explosives tested were "less liable than blasting-powder to ignite inflammable mixtures of air and fire-damp—air and coal-dust—and air, fire-damp, and coal-dust." †

No doubt if what may be termed "working" charges had been used in the experiments, the results would not have been so favourable to the explosives tested, but the experiments of Mr. Winkhaus show that even when working charges are fired unstemmed, there are several explosives so very much safer than the old explosives, that, although they have no claim to be called flameless, they are fairly entitled to be called safety-explosives. It appears probable that the amount of the charge is an element of great importance with reference to the safety of these explosives, and if more was known on the subject safety might be further increased by limiting the amount of an explosive allowed to be fired in one shot-hole.

It would appear from discussions which have taken place on the *Report* that the remarks therein on the influence of the length of stemming may give rise to a wrong impression. In practice, the object of stemming is so to confine the explosive as to prevent blown-out shots, whereas with the stemming used in the experiments this was not the object, and did not prevent the shots being blown out. A blown-out shot is the most dangerous result of blasting in coal-mines, and, with reference to the prevention of the ignition of gas or coal-dust, the stemming is of vital importance. In the regulations for the use of explosives in fiery and dusty mines in France, the minimum length of stemming for charges of different weights is prescribed. The eighth conclusion of the Committee‡ reads almost like a recommendation to use a short length of stemming, in order to be able to fire a missed shot by the insertion and detonation of

* *Report*, Table II., page 19; Table XIV., page 74; and Table XVII., pages 91 and 92.

† *Report*, page 110. ‡ *Ibid.*, page 41.

another cartridge in front of the missed shot. To say nothing of the risk that the added cartridge might not fire the original charge, the amount of stemming which could be placed in front of it would, as a rule, be small, and the risk of its being blown out would therefore be considerable. He (Mr. Atkinson) thought that such a method of dealing with missed shots would be dangerous in fiery and dusty mines.

The lengths of flame recorded as being produced by the explosives tested he regarded as extremely doubtful, and it is to be regretted that some more certain method of verifying them was not adopted.

In the remarks on coal-dust* it is not quite accurate to say that in 1844 "the Government instituted an enquiry into the probable action of coal-dust in the Haswell colliery explosion." The enquiry referred to is doubtless that made by Messrs. Lyell and Faraday, and although they referred to coal-dust as a contributory agent in that explosion, there is nothing to indicate that the enquiry had any special reference to the probable action of coal-dust, nor were any suggestions or recommendations made by Messrs. Lyell and Faraday on the subject of coal-dust. In the following paragraph of the Committee's *Report* it is stated that "the general opinion at the present time is that coal-dust is a real source of danger in coal-mines where blasting is carried on," from which it might be inferred that the "general opinion" was that coal-dust could only be ignited by blasting. Again, in the penultimate paragraph of this section of the *Report* it is not accurate to say that it is enacted in the Coal Mines Regulation Act of 1887 "that in a gaseous or dusty mine an explosive which cannot ignite gas or coal-dust may only be employed."

The meeting then terminated.

---

* *Report*, page 84.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, JUNE 13TH, 1896.

MR. G. P. CHAPLIN IN THE CHAIR.

Mr. E. McGOWAN read the following paper by Messrs. W. R. Bell and E. McGowan on "Haulage at Wearmouth Colliery":—

HAULAGE AT WEARMOUTH COLLIERY.

BY W. R. BELL AND E. McGOWAN.

The sinking of Wearmouth colliery was commenced in 1826, and continued without intermission until 1835, when the maudlin or bensham coal-seam was reached, at a depth of 1,596 feet. The sinking was afterwards continued a further distance of 126 feet to the hutton seam. The maudlin and hutton coal-seams are both worked, and the coals are drawn to bank from the hutton seam level.

The main haulage-ways are three in number, one running north, another east, and the third south-west. Roads branch to the right and left of the main roads, so as to cover the total area of coal to be worked to the shafts. Fig. 1 (Plate XV.) shows the engine-planes, landings, and inclines now in use.

Chair-way and cross sleepers are chiefly used on the engine-planes, as shown in Fig. 2 (Plate XV.), but a heavier, flat-bottomed rail is now being adopted, laid on longitudinal battens and cross sleepers, as shown in Fig. 3 (Plate XV.). The weight of the chair-way rail is 28 lbs., and of the flat-bottomed rail 40 lbs. per yard. The chair-way rail is made in lengths of 12 feet, and the sleepers are 44 inches long, 5 inches wide, and 3 inches thick. The flat-bottomed rail is used in lengths of 15 feet, the longitudinal battens are 17½ feet long, 7 inches wide, and 2½ inches thick, and the cross sleepers are 44 inches long, 5 inches wide, and 3 inches thick. The chair-way is laid similar to the ordinary surface railway, the chairs being pinned to the sleepers, which are placed about

3 feet apart, and keys are driven in between the chair and the outside of the rail. The flat-bottomed rail is fastened by dogs to the longitudinal battens and cross sleepers. The ends of the rails in both cases are fastened together by fish-plates and bolts (Fig. 3, Plate XV.). The gauge or space between the rails is 29 inches.

The tubs used are the same size in both seams, viz. :—Height above rail 45 inches; the inside measurements at the top of the box are, breadth 32 inches, and length 36 inches; the ends taper slightly downwards; the sides are vertical for 27 inches, and then taper downwards, making the size in the bottom 33 inches by 24 inches. The carrying capacity is about 9½ cwts., as filled in the workings. The dimensions of the wheels are:—Diameter 15 inches, width of flange ¾ inch, width of trod of wheel 2½ inches, distance between axles 20 inches, and diameter of axles 2 inches. Length of centre-bar on bottom of tub from centre to centre of bolt-hole 38 inches. The length of the coupling-chain is 14 inches.

The steel ropes in use are of two sizes: the circumference of that on the north engine-plane is 2½ inches, and of those on the other two planes 2¼ inches. The ropes weigh 6⅛ lbs. and 5¼ lbs. per fathom respectively, and are bought in lengths of 3,000 and 3,600 feet. When splicing, the ends of each rope are opened out for a length of 15 feet. At each end of the rope and connecting it with the set of tubs is a chain 90 feet in length, which serves the double purpose of giving warning when the set is approaching (by making a noise on the rollers), and of lengthening or shortening the ropes as the length of the set of tubs may require. For this latter purpose, long links are inserted in the chain at distances of a few feet. The links of the chain have a diameter on the north engine-plane of ⅝ inch, and on the other two planes of $\frac{9}{16}$ inch, weighing 22 lbs. and 18 lbs. per fathom respectively. The total length of haulage and incline-ropes in use at present is about 24 miles.

North Engine-plane.—The north engine-plane, starting from the A pit shaft (Fig. 1, Plate XV.) immediately after leaving the landing enters a stone drift 1,380 feet long, rising 1 in 20 to the maudlin coal-seam. A short distance from the end of the drift a branch-road runs to the north-west, the main road continuing north for about 3,000 feet; where there is a branch road to the north-east.

The haulage is on the tail-rope and main-and-tail-rope systems. The tubs are coupled into sets of 65, which run at an average speed of 10

miles per hour. When the set is going into branch districts, the ropes are changed when the empty set stops at the offtakes. The full set of tubs after coming out of the landing is stopped just over the offtake-points, and the ropes are then again changed. The set is then brought out to the top of the incline. Thus far the haulage has been on the main-and-tail-rope system, but now it is changed. On reaching the top of the drift the speed is reduced, and when sufficient of the set is on the incline, the main-rope is loosed off and the set runs by its own weight, drawing the tail-rope with it, to the shaft, where it is stopped by the engineman putting the brake on the tail-rope drum. The rope is then fastened on to the end of the empty set and drawn up the incline, at the top of which the main rope is coupled.

The hauling-engine is situated at the shaft-bottom. It has two cylinders, each 22 inches in diameter, with a stroke of 48 inches; the steam pressure is about 50 lbs. per square inch, and the indicated horse-power about 200. The drums have a diameter of 6 feet and a breadth of 2 feet. The shaft is 9½ inches in diameter where the drums are placed and 10½ inches where the clutch is attached. About 1,300 tons of coal have been brought out to the shaft in a day by this engine.

East Engine-plane—To the east of the shafts the maudlin coal-seam is worked, approached by a level stone-drift, the natural conditions being such that at some distance from the shaft the maudlin seam is found at the same level as the hutton seam is at the shaft (Fig. 4, Plate XV.). Some distance further to the south east (at the point R) the coal-seam begins to dip heavily inbye from the shaft. The coals in this case have to be brought up an incline, necessitating a contrary arrangement to that of the rise stone-drift in the A pit, north engine-plane. The haulage from the shaft to the top of this dip drift (the return wheel is fixed at *R*) is by the main-and-tail-rope system, but afterwards down the dip drift to the working-face it is by the single or main-rope system. When the empty set of tubs reaches the top of the incline the tail-rope is loosed off and the tubs gravitate down to the bottom of the incline, drawing the main-rope with them. The distance from the top of the incline to the far landing is 3,420 feet, and the difference of level is 167 feet, or a dip of 1 in 20·5. The heavy gradient allows only short sets of 37 tubs to be run.

The hauling-engine, which is geared, has two cylinders each of 14 inches diameter with a stroke of 24 inches, a steam-pressure of 70 lbs. per square inch, and the indicated horse-power is 67. The drums are 6 feet

in diameter, and have a width of 18 inches. The spur-wheels are 6 feet 5 inches, and the pinion wheel is 2 feet 11¾ inches in diameter, with a pitch of 2½ inches and breadth of face of 8⅞ inches. The shaft is 6½ inches in diameter and the journals 5 inches long. The average speed from the far-off landing to the shaft (which includes the slower speed in coming up the heavy bank) is about 9½ miles per hour. About 700 tons per day have been brought to the shaft from the present landings.

South-west Engine-plane.—The south-west engine-plane passes for some distance through a stone-drift which cuts the hutton coal-seam at a rise fault of 36 feet. The engine-plane continues in the hutton seam to a dip fault of 126 feet, which, curiously enough, is the exact difference of level between the two coal-seams, so that on the dip side the maudlin seam is on the same level as the hutton seam is at the rise side (Fig. 4, Plate XV.). The maudlin coal-seam alone is worked beyond this fault, and as it rises heavily to the west, a self-acting incline is worked.

The haulage is effected by an altogether different arrangement from that adopted in the other two main districts. The main road runs to the maudlin seam and a double line of rails is laid the whole length, so that as the empty set runs in the full one runs out. The branch roads to the hutton seam are both situated on the right-hand side of the maudlin engine-plane (Fig. 5, Plate XV.), and the haulage is on the main-and-tail rope system. It is necessary, in order to change the ropes, that the sockets *S* (Fig. 5) should always be placed opposite the offtakes; this can only be managed by running two consecutive sets into the maudlin coal-seam. For instance, suppose that one set is run into the maudlin seam, it is clear that the sockets will not be in the required position; but if a second set be run to the maudlin seam, the ropes will be brought back to their original position, and rope-couplings can now be made for the set to go into either of the hutton seam districts.

This changing of the ropes is necessarily done whilst the sets are in the landings. The empty set goes into the hutton seam, the full set is brought out, and when it reaches the shaft the sockets are in the same position as before, and the ropes can be changed for the other districts.

The hauling-engine is of the same dimensions, and works with the same steam-pressure as that on the A pit or north engine-plane. About 1,000 tons of coal are being brought to the shaft in a day by this engine from the present landings.

General Remarks.—A full coal-tub is placed at the fore end of each empty set, and on the south-east engine plane two full tubs are placed at

the front of the set when going into the dip landings. The full tubs tend to steady the set of empty tubs and prevent them from jumping the rails.

Electric bell-signals are used on all the engine-planes, and each landing, in addition, is connected by telephonic communication with the shaft.

The return rope-wheels have an extreme diameter of 7 feet, with a flange of 5 inches, the diameter of the rope-trod being 6 feet 2 inches. The diameter of the axle is $3\frac{3}{4}$ inches.

Two sizes of rope-rollers are in use, of the lengths of 15 inches and 9 inches respectively, the longer being placed near curves. The diameter of the rollers is $5\frac{1}{2}$ inches, with a flange of 1 inch, and the diameter of the axle is $\frac{3}{4}$ inch. The bearings are fastened to wooden briars of such a length that each end is fastened on to a sleeper. The weight of the rollers is 11 lbs. and $9\frac{1}{2}$ lbs. for the long and short ones respectively.

Curve-wheels are 39 inches in diameter and $6\frac{1}{2}$ inches deep, and the diameter of the axle is 1 inch. Drum-sheaves are 18 inches in diameter, with a depth of $9\frac{1}{2}$ inches.

The points are very similar to ordinary railway points. Those at the landings are self-acting, so that the empty set coming in must take its proper side, and when the full set is coming out, the points being loose are pushed over. The lever is balanced, and bent so that it will only hang in one position. At offtake-points, which have to be changed according to the direction in which the set is going, the lever is straight and works between two flat semi-circular plates, in which holes are bored, so that a pin can be inserted to keep the lever in a fixed position.

At the offtakes, winches are used to pull the ropes off the drums, so that they may be conveniently coupled together.

At the pit-bottom there are five multitubular boilers fitted with copper fire-boxes and tubes working at a steam pressure varying from 45 lbs. to 75 lbs. per square inch. The tubes are $11\frac{1}{2}$ feet long, $2\frac{1}{4}$ inches in diameter, and there are 45 of them in each boiler. The length of the fire-box is 4 feet, the total length $18\frac{1}{4}$ feet, and the diameter $3\frac{1}{2}$ feet. Only three boilers are used at one time, the other two being held in reserve.

In the maudlin coal-seam there are four egg-ended boilers, each 45 feet long and 5 feet in diameter. They are fired with Jukes furnaces, driven by a small engine, with a cylinder 6 inches in diameter and 12 inches stroke. The steam for this engine is taken direct from the boiler, and the pressure can be altered so as to drive the engine at any speed. Of these four boilers only three are in use at any one time.

The steam from the maudlin boilers and from the pit-bottom boilers is taken by pipes into a receiver, and by an arrangement of valves the hauling-engines can be driven by the steam from either set of boilers separately or from both.

The boiler-fires are fed with return air (the entire ventilation of the colliery is effected by means of a furnace), which afterwards passes into the upcast shaft, and thus assists the ventilation.

Mr. R. R. SIMPSON moved, and Mr. T. SIMPSON seconded, a vote of thanks to the writers of the paper.

The meeting then terminated.

To illustrate Messrs W.R.Bell & E. Mc Gowan's Paper on "Haulage at Wearmouth Colliery."

FIG. 1.

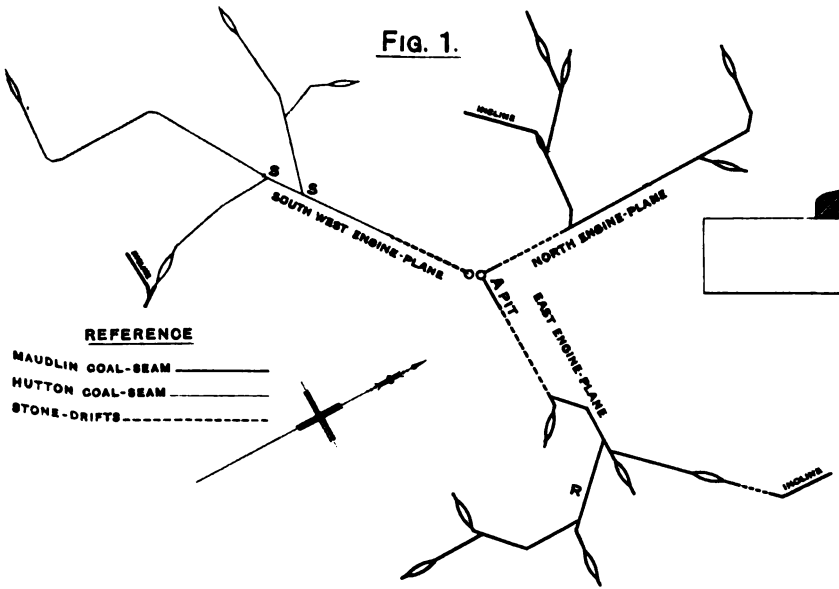


FIG. 2.

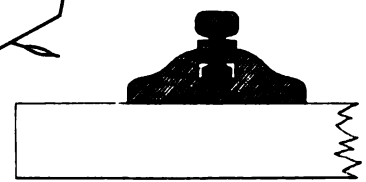


FIG. 3.

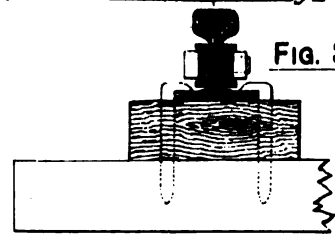


FIG. 5.

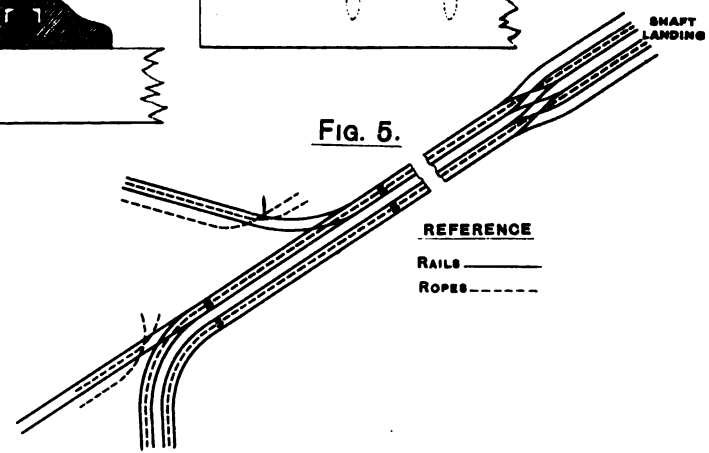
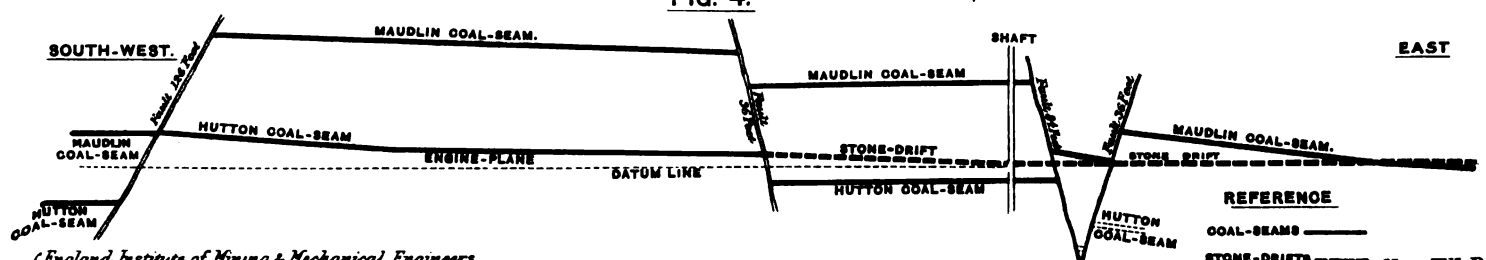


FIG. 4.



And.r Reid & Comp.y L.td Newcastle on Tyne.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE BULL HOTEL, WAKEFIELD, JUNE 13TH, 1896.

MR. JOHN NEVIN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. THOMAS HARDING CHURTON, Electrical Engineer, 5, South Parade, Leeds.

Mr. ALFRED CROSSLAND, Mechanical Engineer, Middleton, near Leeds.

Mr. DAVID RUSSELL, Mining Engineer, Thorncliffe Collieries, Sheffield.

ASSOCIATES—

Mr. ALFRED BEDFORD, Colliery Deputy, Church Street, Emley, Wakefield.

Mr. JOHN HOBSON, Colliery Under-manager, Crigglestone, Wakefield.

Mr. JOHN PARTRIDGE JENKINS, Civil Engineer's Assistant, 135, Whitelea Road, Swinton, Yorkshire.

Mr. EPHRAIM RAMSDEN, Colliery Under-manager, Crigglestone, Wakefield.

Mr. WILLIAM ROBINSON, Colliery Under-manager, Calder Grove, near Wakefield.

Mr. CHARLES SOWERBY, Colliery Deputy, Town End, Emley, Wakefield.

PROPOSED ALTERATION OF RULES.

Mr. H. B. NASH gave notice that at the ensuing Annual Meeting he would move an alteration of Rule 9, that after the words "eligible for re-election after being one year out of office" instead of the words "voting-papers with a list of the officers shall be posted to all members of the Institute," there should be substituted the words, "and the election of all officers shall be by ballot, and ballot-papers with a list of officers shall be posted to all members of the Institute," etc.

DISCUSSION ON MR. RANKIN KENNEDY'S PAPER ON "ELECTRICAL MACHINERY FOR MINES."*

Mr. A. W. BENNETT (Leeds) said it seemed to him that a combined system of alternating and continuous currents would eventually meet the requirements of the mining engineer. The majority of electric lighting central stations were worked on the alternating-current principle, and it seemed to be in every way favourable for application to mining work. He (Mr. Bennett) obtained a slow motion for an electrical pump by gearing down ordinary motors, and used his combined current for the purpose; but unfortunately he did not get a much higher percentage than with the ordinary transforming motion. A member had said that he should not like to carry 3,000 volts into the pit; but, in a continuous-current motor running 500 volts at the terminals, in the event of any accident or break they could not tell what electrical force they might have in that current—it might rise to over 3,000 volts. If they could adopt a system that obviated the difficulty of using currents of 500 volts at the motor, and enabled them to use only 100 volts at the motor, transforming above or below ground, the whole of the transformer being thoroughly and strongly enclosed, it looked like obtaining a solution of one of the difficulties in electrical working.

Mr. T. B. A. CLARKE (Tankersley) said that no doubt alternating-current dynamos were well adapted for lighting, but it was doubtful, at the present stage, whether they were adapted for driving machinery where the load was subject to constant variations, and that was a crucial point. No doubt, it was possible to deal with alternating currents down the pit, and considerable saving in cables might be effected by the use of nigh-tension currents. There was no case on record of a continuous current at a pressure of 500 to 700 volts having caused death, or even serious damage. It was possible, after breaking the current in a certain way, to get an induced shock which was very heavy. If high pressures were used, there must be considerable expense incurred in protecting the wires, as any accident from a pressure of 1,500 volts would cause almost certain death. He thought that the alternating-current system had not been more extensively used owing to there being no efficient alternating motor. For lighting, the alternating-current system was efficient, as a great deal of power could be distributed over a large area at a small cost. Many lighting installations were now being erected on the continuous-current system, as at Bradford, as a large revenue ensued from the

* *Trans. Fed. Inst.*, vol. x., pages 98 and 457; and vol. xi., page 125.

use of motors, which could not be driven by alternating current. If Mr. Kennedy had an alternating-current motor which would start under a considerable load, and run steadily under constant fluctuations of load, there would be a great future before it.

Mr. E. Brown (St. John's Colliery, Normanton) remarked that if Mr. Kennedy's results could be got from his motor, it would be very suitable for use in mines. He (Mr. Brown) did not approve of using one machine for many classes of work. If the current from one dynamo was used for several purposes, it might be required for hauling and pumping at the same time as for lighting. A continuous current of 700 volts was used at the St. John's collieries, and no one had received a shock sufficient to hurt him. There was not half the danger that people thought about electrical transmission, and the cost was much less than that of any other system. Electricity was superior to any other system for the transmission of power in mines free from gas.

Mr. Rankin Kennedy said that the discussion seemed to have turned on alternating-current motors. In towns lighted by electricity, a motor was used which could be run only at one speed, and that motor had not been referred to in his paper, because it could not be used in mines; it had both commutator and brushes. The polyphase-current motor had no brushes: it could start with any load, and run with any variation of load. In answer to Mr. Clark, he might mention that not long ago a man was killed on the railway at Bush Mill, where the pressure was not supposed to exceed 250 volts, and there were other instances of accidents with continuous currents of 300 volts. Any pressure which would work a continuous-current motor would also work an alternating-current motor, but with the latter there was the advantage of being able to use high pressure for transmission and low pressure for the motor, so that the alternating-current motor could really be worked at a much lower pressure than the continuous-current motor.

A further advantage was in the saving of the cost of copper mains. The transmission at a higher pressure enabled a 7/20 wire to transmit the power for a 12 horse-power motor, whereas a 7/15 wire was required for an ordinary continuous-current motor at 300 volts—the one lead cost £32 and the other £84 per mile, a difference exceeding the cost of transformers. A further gain was obtained by high pressure transmission—the reduction of the loss in the line to one-half of what it was in the 300 volts continuous-current system. The loss in the line was taken at $1\frac{1}{4}$ volts per 300 feet with the thinner wires and at $2\frac{1}{2}$ volts with the thicker and more expensive wires.

Another advantage of the alternating-current over the continuous-current system was that 300 volts at least must be used at the coal-cutter with the latter, whilst 100 volts could be used with the former system, a very considerable advantage. Although an alternating-current motor was slow to start, it was not dangerous to stop it; but the danger in the continuous-current motor was in stopping it, especially by force, such as by jamming or a fall of coal on the cutting machinery, in which case violent sparking took place. The alternating-current motor could be stopped by force without the slightest spark: in fact, a good alternating polyphase motor protected itself because no more than two or three times the normal current could pass, when it was stopped. No continuous-current motor could stand such a test.

Polyphase motors showed as high an efficiency as any continuous-current motors. In mining work, the stopping and starting of polyphase motors had to be accomplished without an unnecessary number of switches and resistances. Some efficiency was sacrificed to secure extreme simplicity in the working of the motors, because in starting the polyphase motor, as in starting the continuous-current motor, some resistance must be placed in the circuit to prevent sudden increased current when switched on.

The question of working one machine for two circuits was only advantageous where they would be likely to run the motor pressure at double the pressure for lighting—where they wanted 220 volts for lighting they might run 440 volts at the motor. There was no reason why the lighting and power motor should not be run from one dynamo if a double-circuit continuous generator was used.

The system described was not in use at any colliery, but experiments were being made. Alternating machines could be run at various loads, starting from nothing up to full speed.

The discussion was adjourned.

DISCUSSION ON MR. T. SCOTT-ANDERSON'S PAPER ON "ELECTRIC WELDING."*

Mr. RANKIN KENNEDY said that in his experience cast-iron could not be electrically welded by the arc-process.

Mr. T. W. H. MITCHELL said that Mr. Anderson stated that he had not seen any satisfactory welding of cast-iron.

* *Trans. Fed. Inst.*, vol. xi., page 40.

Mr. RANKIN KENNEDY said that copper welded by the arc-process lost 40 to 50 per cent. of its strength at the joint: the fusion of the flange in a copper joint weakened it at the junction of the flange where strength was required.

Mr. E. BROWN (Normanton) said that in the patching of a boiler-plate hammering was necessary, but in the case referred to by Mr. Anderson hammering seemed to be impossible. Was it sufficient to lay one plate on to another and fuze them together? Gentle hammering was mentioned in the other cases, but in the case of the boiler-plate it was not mentioned. Were the repairs effected without hammering?

Mr. RANKIN KENNEDY understood that the electric welding by the arc-process could be effected without hammering, but special plant would be required.

Mr. BROWN said that some of the plates, etc., mentioned in the paper were hammered, and he should like to know whether hammering was necessary or merely precautionary.

Mr. A. W. BENNETT said that there was no rule as to what power would be required for such and such work, and a large electric plant was required for an output of 250 ampères.

The discussion was adjourned.

DISCUSSION ON MR. ROBERT MARTIN'S PAPER ON "THE TREATMENT OF TIMBER FOR USE IN MINES."*

Mr. W. E. GARFORTH (Normanton) said that in a previous discussion some of the members spoke of the difficulty in dealing with the props for a mine producing 1,000 tons of coal a day, though they admitted that they had tried it with advantage. Other people thought that one workman would be able to dip all the timber required for a large colliery. He proposed to use some of the treated props, and at some future time he would be glad to lay his experience before the Institute. He might mention that there were great differences in the hydrometrical state of the air of mines. At the West Riding collieries in the silkstone coal-seam, 1,440 feet deep, there were 7 or 8 degs. between the readings of wet and dry bulb thermometers; and in the Stanley main coal-seam, 240 feet deep,

* *Trans. Fed. Inst.*, vol. x., page 531; and vol. xi., page 90.

the difference in readings varied from 1 to 1½ degs. between wet and dry bulb thermometers. One of the members spoke of the weight that timber would carry. He spoke of a batten 9 inches by 3½ inches breaking at 45 cwts., whereas they knew from experiments made with a press, capable of giving a force of 500 tons, that a prop 7 inches in diameter and 6 feet long would carry a weight of 137 tons.

Mr. E. W. THIRKELL (Oaks Colliery) said that on the occasion of the visit of The Federated Institution of Mining Engineers to Leeds on February 15th, 1894, Prof. Goodman made some tests on pit-props, an account of which he ventured to think would be interesting. The results were as follow:—

1.—A prop of Norwegian fir, 7 feet long, 21 inches in girth at the bottom, 20 inches in the middle, and 18 inches at the top, began to crack with about 20 tons, and broke at 2½ feet from the top at 28·46 tons.

2.—A prop of similar wood, 6 feet long, 19 inches in girth at the top, 19½ inches in the centre, and 20 inches at the bottom, broke at 29 inches from the bottom at 90·08 tons. This was a well-seasoned dry prop.

3.—A similar prop to the above, of green English larch, but not seasoned, broke at 36·00 tons.

4.—A Firth steel prop, 6 feet long, and 5 inches by 4 inches, with a flange or web $\frac{7}{16}$ inch thick, and 5 square inches of steel in section, weighing 50 lbs. per yard, when tested bent with a snap, and appeared to collapse with a strain of 81·05 tons. The deflection was 5¼ inches from a straight line.

5.—A steel prop, similar to the above, broke at a strain of 96·80 tons.

The most interesting point in connexion with the above detailed tests was the great difference in strength between a prop in a seasoned or dry and in a green condition. Prof. Goodman stated that "90·08 tons was a very exceptional result, as timber varied very much in its strength, probably due to shakes and other defects. Green props usually carried 35 to 40 tons before giving way."

It would be interesting to have a number of tests made on a number of props, both seasoned and green, because if there was anything like the difference shown by the above tests, it would certainly be worth while to take steps at collieries to store the props on a dry floor and under cover, and generally to take more care than is usually done to preserve them when in stock.

Mr. E. BROWN said that the breaking strain referred to in Mr. Martin's paper was that of timber used as a cross-bar, set on props.

Mr. W. E. GARFORTH said that according to Mr. Martin's paper there was no difference between salted and unsalted timber as regarded breaking strain. Some scientist had stated that the strength of timber varied directly as the weight, but that was not borne out by experiment. He had seen very close-grained timber weighing much more than larch, which had broken with a less weight than open-grained timber. The breaking strain of English oak was about as 850 to 350 lbs. for larch, 750 lbs. for ash, and 500 lbs. for American walnut.

The discussion was closed.

DISCUSSION ON MR. H. ST. JOHN DURNFORD'S "NOTES ON THE SINKING OF THE NO. 1 PIT AT THE ACKTON HALL COLLIERY," ETC.*

The PRESIDENT said that Mr. Durnford had written that the workings had "not yet been driven far enough in the proper coal-seam to make any further discovery."

Mr. J. O. GREAVES (Wakefield) said that he should like to know the result of the drivings to the westward.

The discussion was adjourned.

DISCUSSION ON MR. HARGRAVE WALTERS' PAPER ON "LEAD AND LAP OF WINDING AND OTHER ENGINES."†

Mr. E. BROWN said that it was news to him to hear of an engine running with a § inch lead, and the compression must have been enormous. The arrangement for moving the eccentrics on the shaft would not stand rough hard work. All the driving would be done by the lever-and-pin, which had to move the eccentrics back and forward. He should not be inclined to add to the labour of the engineman, who, in some cases, drew 1,000 tons in a day of 8 or 9 hours.

* *Trans. Fed. Inst.*, vol. x., page 444. † *Ibid.*, vol. xi., page 64.

The PRESIDENT agreed that the engineman should not be given an extra handle to attend to.

Mr. H. WALTERS wrote that the lead was $\frac{1}{8}$ inch, and the compression was not excessive, but just what it should be at the speed. The eccentric gear will bear any test or rough work. It was not necessary to tax the engineman, as the gear could be operated automatically.

The discussion was adjourned.

The meeting was closed.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ROOMS OF THE ROYAL SCOTTISH SOCIETY OF ARTS, EDINBURGH, JUNE 13TH, 1896.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. ROBERT ADDIE, Langloan Iron-works, Coatbridge.
Mr. JOHN FLEMING, P.O. Box 1878, Johannesburg, Transvaal.
Mr. CHARLES D. GEDDES, 21, Young Street, Edinburgh.
Mr. JOHN HALLIDAY, Blackhill Colliery, Maryhill.

DISCUSSION ON MR. DUGALD BAIRD'S PAPER ON "THE DUTY OF PUMPING-ENGINES."*

Mr. ROBERT MARTIN (Portobello) said that, with the exception of some notes by Mr. J. T. Forgie,† this was the only paper on the duty of pumping-engines in the *Transactions*. In text-books and hand-books on mining, in common use, very little reference is made to this subject, and then so vague as to be of little service. Mr. Baird's paper will, no doubt, be studied, and be of considerable use to practical engineers, not only as to the duty of pumping-engines, but as to the economical use of steam at collieries.

It is to be hoped that engineers who are authorities on this subject will agree that Mr. Baird's easy method of testing is neither empirical nor unscientific. Considering the very inferior fuel used at most colliery steam-boilers, and the other difficulties involved, tests based on the water evaporated would seem to be the more accurate way of obtaining fair com-

* *Trans. Fed. Inst.*, vol. xi., page 94.
† *Trans. Mining Institute of Scotland*, vol. xiii., page 65.

parisons, if not actual results. The author of a book on *Indicator Diagrams and Engine and Boiler Testing* recommends steam-users to measure the water used by means of a meter on the heater feed-pipes, as well as the fuel consumed, the latter only generally being done. He says:—"Comparing only the weight of the fuel used with the power developed possesses the great disadvantage of not separating the working of the boiler from that of the engine," and he adds, among other reasons, that—

> By measuring the water as well as the coal, the figures obtained would give the number of pounds of water evaporated per pound of coal, and the number of pounds of steam used per indicated horse-power by the engine, so that the efficiency of the engine and of the boiler would be obtained separately instead of together. The value of this opinion will be seen from the following illustration:—Suppose that a compound-engine and boiler are using 2½ lbs. of coal per indicated horse-power. This would be a fair result, but not very good, and would probably be left alone by most mill-owners. If, however, for example, the 2½ lbs. of coal per indicated horse-power were made up thus: 10 lbs. of water evaporated per pound of coal, and 23½ lbs. of steam used per indicated horse-power, it would be seen at once that the engine was much at fault, and should have attention. On the other hand, suppose that the engine used 14 lbs. of steam per indicated horse-power, this would mean that, when using 2½ lbs. of coal per hour, only 6 lbs. of water were evaporated per pound of coal, in which case the boiler would be much at fault.

Mr. Baird might tell the members what improvements on the present, or what change of type from the engines that he described, are necessary, so as to bring them up to the ideal standard of 100,000,000 foot-pounds of duty per cwt. of coal burned, and this, he says, "it is quite possible to get." He might also give the members his opinion as to the type of engine that he would substitute for the Davey differential and duplex direct-acting compound and condensing pumping-engine, raising 300 to 600 gallons of water per minute, in 700 feet heads, from a vertical depth of 2,100 feet, on a slope varying from 50 to 60 degs. inclination. These conditions are doubtless beyond the reach of the famous Cornish engine. At Niddrie, a Moore hydraulic pump is being erected, at a distance on the slope of 1,800 feet from the surface, to raise 500 gallons of water per minute against a head of 700 feet. The steam-engine, on the surface, is placed close to the boilers, and is to be worked with a steam pressure of 100 lbs. per square inch—expansively, compound, and condensing. By and by, it will be interesting to compare this plant with the Hathorn-Davey pump, supplied with steam from the surface on the same station, it is intended to duplicate.

In connexion with the water used per hour during the dead-loss tests, Mr. Baird might tell the members the length of steam-pipes in the shaft and underground in each case. A locomotive is said to consume a fifth of

the fuel when at rest that it does when in motion. At pits the dead-loss will probably always be greater, the machinery not being so compact, and being more exposed, and will be, less or more, according as the steam-pipes are properly protected by non-conducting material, and leakages at bad joints prevented. When the dead loss is 48 per cent. of the total water evaporated, the efficiency of the steam-pipes is almost as important as that of the engine.

There can be no objection to Mr. Baird's deduction of 5 per cent. from the theoretical to get the actual discharge, except that it lowers the duty of the engine if the glands and valves are in order. At Niddrie collieries, the discharges of two pumps were carefully measured: one, with a head of 750 feet, and discharging 272 gallons of water per minute, lost 2 gallons; the other, with a head of 660 feet and 301 gallons discharge, lost only 1 gallon. To have constantly to "run back water" from the mains to keep the pump solid is not a good feature in a pumping arrangement.

Mr. Baird gives the members the temperature of the feed as it reaches the boilers. This is a source of economy often neglected at a colliery, where the steam from winding-engines is generally blown into the air. At Niddrie collieries, the feed was heated by passing through a Berryman heater, into which the steam from two winding-cylinders (40 inches) was exhausted. The water was heated up to 130 degs. Fahr., and many of the impurities in the water were removed. It was determined, owing to back pressure, to exhaust only one cylinder into the Berryman feed-water heater, and, as an experiment, another heater of the old-fashioned style was provided for the second cylinder. The second feed-heater consists of an egg-ended boiler, 30 feet long and 5 feet in diameter, placed horizontally, where the exhaust steam came into direct contact with the water. Both are working under the same conditions. The latter was found to be the more effective, and a much cheaper plant. The firemen prefer to take most of the feed-water from it at a temperature of from 196 to 206 degs. Fahr.

Mr. Baird speaks of "lowering the water" in the boilers in the dead-loss tests to "prevent priming." Boilers must be very prone to prime if they do it under these circumstances. Priming, when it does occur, is an evil not easily mitigated, a source of waste, and injurious to the slide-valves, pistons, and cylinders; and where there is heavy winding a sudden influx of water may cause the cylinder-covers to be knocked off, or joints blown out. A steam separator or drier was fixed to one of the winding-engines at the Niddrie collieries, supplied with steam from four Cornish boilers, almost constantly priming. It did no good whatever. A steam

receiver, 15 feet high and 3 feet in diameter, was erected between the boilers and the engine, the steam entering at the bottom and being drawn off at the top, passing through two perforated plates on its way. The water collected is removed by means of a trap. The engine now receives perfectly dry steam, runs at the highest speed quite smoothly, requires less lubrication, and is always in better condition. Unless boilers are over full there is no priming.

In another case, owing to the excessive drain of steam, this arrangement failed to stop priming, though it has greatly reduced it; but it effectually prevents the dirty, limey water from getting into the cylinders; it is all caught and run off by means of a steam-trap.

Mr. MALCOLM (Arniston) said that many pumping-engines connected with collieries could not be tested, owing to the steam being applied to other purposes.

The PRESIDENT said that there was an error in Table I. in Mr. Baird's paper.* The theoretical quantity of water pumped was given in the first column as 753 gallons, in the second column as 900 gallons, and in the third column as *nil*.

Mr. BAIRD said that the third pump did not pump to the surface, and its work was included in the 900 gallons stated in the second column.

The PRESIDENT asked Mr. Baird how he got over the difficulty with his steam-pipes for engines placed underground? There would be a considerable variation in them, and sometimes they would be well covered, and sometimes not, and sometimes longer and sometimes shorter, so that the loss would not always be the same.

Mr. BAIRD said that he included the loss due to the steam-pipes in the dead loss, and he included the total in his tables.

Mr. A. M. GRANT (Kilmarnock) said that he did not quite see what was the object to be attained by carrying out the tests described in Mr. Baird's paper. If the tests were put into practical use, they would involve a great amount of trouble and expense, and would require to be done from time to time. The proposal that he made for testing a pump was to take indicator-diagrams from the engine. He still maintained that for ordinary practical work this was the proper way to obtain the duty of an ordinary pumping-engine.

Mr. BAIRD remarked that indicator-diagrams had been taken, but they had not been published in the *Transactions*.

* *Trans. Fed. Inst.*, vol. xi., page 100.

The PRESIDENT asked whether Mr. Grant maintained that it was sufficient to take an indicator-diagram?

Mr. GRANT answered no; but remarked that it was a good practical test.

The PRESIDENT thought that Mr. Baird showed he could get a fairly accurate test by the method which he employed. What was wanted was the efficiency of the engine, and they naturally neglected to state the kind of coal that they used and the boiler that they were using, because these differed at different collieries. In a bucket-pump, he should imagine that leakage in the bucket would affect the amount of work done, and an allowance for loss of 5 per cent. would not be very accurate.

Mr. D. BAIRD remarked that in almost every case it took as much steam to pump a smaller quantity of water as the full quantity per stroke, whether the loss was due to leaking valves or to the buckets passing water.

Mr. MALCOLM said that, if Mr. Baird had a catch on his plunger, and water was running back, and supposing that the height of column was 600 feet and running back 300 feet, would the indicator-diagram register the same amount of pressure when running back?

Mr. BAIRD replied in the affirmative.

The PRESIDENT said he thought that Mr. Baird was quite right as regarded the plunger, as they had always the statical pressure, if any water was being delivered.

Mr. MUIR (Kelty) said that a pound of coal would not evaporate as much steam at a pressure of 80 lbs. per square inch as at 53 lbs. There might not be a great difference in the amount of coal burned, but there would be a great difference in the efficiency of using steam at a pressure of 80 lbs. as against 53 lbs. per square inch.

The discussion was adjourned.

The SECRETARY then read the following paper on "The Health Conditions of Coal-mining," by James Barrowman:—

THE HEALTH CONDITIONS OF COAL-MINING.

By JAMES BARROWMAN, Mining Engineer.

A few years ago a candidate for parliamentary honours in addressing an audience of colliers in Hamilton, exclaimed in a fine frenzy that he saw death stamped on their faces. The statement was not received with that enthusiasm which the speaker no doubt expected, probably because it lacked the flavour of flattery, so agreeable to every one, and was not self-evident enough to be accepted by the audience as true. Who can tell what influence these few words had in placing him at the bottom of the poll?

That exclamation illustrates a very widespread belief, which frequently finds utterance at miners' meetings and in speeches delivered in the miners' interests, namely, that the coal-mining industry is particularly unhealthy. If it be so, it is well that the fact should be firmly established and widely known; if it be not so, the true state of the matter should be published no less widely.

It cannot be denied that coal-mining is a dangerous occupation. With, perhaps, the exception of the railway industry, it is more prolific in accidents, fatal and otherwise, than any other occupation in this country. The annual reports of the Inspectors of Mines serve not only to keep this fact always before us, but they preserve a correct record of the nature and number of mining accidents. They also show, however, the progressive improvement that has taken place as regards safety in the occupation of the collier, and this has some bearing on the figures relating to health, referred to later on. Comparing the figures for 1855, with those for 1894, as shown in Table I., it will be seen that while the number of fatal accidents has fluctuated little, maintaining an average rate over the past forty years of 1,061 per annum, the output and the number of persons employed have increased almost threefold.

Table I.

Year.	Output of Coal in the United Kingdom. Tons.	Persons Employed Above and Underground.	Fatal Accidents.	Deaths per 1,000 Tons Raised.	Deaths per 1,000 Persons Employed.
1855	64,453,079	242,719	955*	·015	3·9
1894	188,277,525	705,240	1,127*	·006	1·6

* Annual mean 1,061.

There is no doubt that the health conditions of coal-mining have also greatly improved within the same period This can, of course, be said of all occupations, and of the people as a whole; but apart from this general improvement, we want to know if there are diseases peculiar to coal-mining which have the effect of shortening the life of the miner, or, if those diseases which are common to all are aggravated by mining conditions to such an extent as to justify the statement that the coal-miner is a short-lived man. When we consider that about one-fifth of the whole male population of the United Kingdom, between the ages of 25 and 65, are miners, it will be recognized that the question is one of some consequence.

It is matter for surprise that this subject has received little attention in this country. As regards Scotland, there are no statistics published from which a comparison can be made of the health conditions of persons engaged in different occupations. Mortality tables for England and Wales have been published; but there are no statistics made up for the country as a whole, and those which are available are fifteen years old. It may, however, be safely assumed that if the conclusions arrived at after examination of the particulars collected fifteen years ago are well founded, the results would be more favourable if later statistics were available, seeing that there has been an obvious advance towards a better state of things. Apart from the statistics referred to, there are probably valuable particulars which have been collected by individual observers in isolated districts, but these appear to be few.

As to whether there are any diseases peculiar to the miner's calling, there is evidence that, with one, or perhaps two exceptions, there are none such. These exceptions are: an affection of the eyes, termed "nystagmus;" and, in a lesser degree, that disease of the respiratory organs which usually goes by the name of "miners' asthma."

Nystagmus, although not a prevalent affection, is one with well-marked symptoms directly traceable to the posture of the collier while at work. The symptoms are oscillation, with more or less of a rolling motion of the eyeballs; giddiness, with headache, and the appearance of objects moving in a circle, or lights dancing before the eyes. In severe cases the person affected may stumble and be so much inconvenienced as to be obliged to stop work. Dr. Simeon Snell, of Sheffield, has given this disease special attention for about twenty years, and has published the results of his investigations,* which show beyond all reasonable doubt that nystagmus is confined almost entirely to those underground workmen

* *Miners' Nystagmus.* By Simeon Snell, 1892.

who are engaged in holing or under-cutting the coal, and is due to the miner's habit of looking upwards, above the horizontal line of vision, and more or less obliquely while at work lying on his side. It has been observed also in firemen and others who have occasion frequently to examine the roof, turning the eyes obliquely while doing so. Any other occupation in which the person may habitually turn the eyes upwards and sideways will induce nystagmus; but such cases are so rare that this trouble may be regarded as one peculiar to mining. Turning the eyes downwards yields temporary relief; but there seems to be no permanent cure for it except abandonment of the kind of work that gave rise to it.

It has been alleged that the use of safety-lamps in the mines, giving less light than the open candle or lamp, has aggravated this disease; but the careful and long continued observations of Dr. Snell, and of Mr. A. H. Stokes,* prove that there is no connexion between the use of safety-lamps and the alleged increase of nystagmus. The number of miners is on the increase, and greater attention has been given of late to this affection than formerly, which circumstances sufficiently account for the supposed relative increase in the number of cases. Other specialists in this country and on the Continent confirm the conclusions of Dr. Snell.†

The disease, called miners' asthma, with which a characteristic black spit is associated, cannot be said to be special to mining in the same sense as nystagmus is, as there are other occupations in which a similar disease is prevalent, such as those of quarriers, masons, and pottery makers; still the conditions of underground occupation appear to be conducive to the extension of this and related diseases of the respiratory organs. It is clear to an ordinary observer, that, within the last quarter of a century there has been a great improvement in coal-miners in this respect, and that those who suffer from diseases of the respiratory organs are relatively fewer now than they were twenty-five years ago. We do not require the evidence of vital statistics to convince us of this, and we can have no difficulty in attributing this better state of things to the great improvement in ventilation effected within the time mentioned.

But it is from a comparison with the workmen in other occupations that the most definite results as to the health conditions of mining are to be got. The information available for the purpose is contained in a series

* *Reports of H.M. Inspector of Mines for the Midland District*, 1890, 1891.

† Dr. Tatham Thomson, *Lancet*, 1891, vol. i., page 311; Mr. Jeaffreson, *British Medical Journal*, 1887, vol. ii., page 109; and Dr. Dransart, *Journal d'Oculistique du Nord de la France*, August, 1891.

of tables prepared by Dr. Ogle, the superintendent of statistics in the general register office, from particulars collected at the census of 1881, and from similar figures collected by his predecessor, Dr. Farr, at earlier dates. In Dr. Ogle's tables, six coal-mining districts in England and Wales are selected, namely, (1) Durham and Northumberland, (2) Lancashire; (3) the West Riding of Yorkshire; (4) Derby and Nottinghamshire; (5) Staffordshire; and (6) South Wales and Monmouthshire. It is to be regretted that there are no published statistics for Scotland.

Dr. Ogle gave evidence, in 1892, before the Royal Commission on Labour, and then submitted a series of tables, an abstract of one of which appears on the following page (Table II.). Table II. shows the number of deaths that took place annually in the years 1880, 1881, and 1882, in 116,261 males of each occupation stated, of whom 75,396 were between 25 and 45, and 40,865 between 45 and 65 years of age. This population was selected as being that in which 1,000 deaths of clergymen occurred annually, being the lowest death-rate of all. Those described as coal-miners include aboveground as well as underground workers in connexion with collieries. The results shown by Table II. are very different from what popular belief would have led us to expect.

Comparing the deaths of coal-miners in the six districts referred to under the several headings in Table II. with the deaths of all males of a corresponding age in England and Wales, we find that, with only two exceptions, the death-rate of coal-miners is the lower. These exceptions are accidents and diseases of the respiratory organs. We should expect these two causes of death to rank high with miners; but the comparison in the case of the other causes of death is so favourable for miners, that, on combining the figures for all causes of death, including accidents and diseases of the respiratory system, the death-rate of the coal-miner still stands lower than the average of the country. It is noticeable also, that if the coal-mining districts be taken separately, the deaths of miners in each, with the one exception of South Wales, are less than the deaths of all males in the same district.

In case it may be thought that comparison with all males is not a fair one, let some of the occupations be selected to which dust or high temperature, or both, are incident, and still the comparison is in favour of the coal-miner. The baker, the blacksmith, the mason, the wool-manufacturer, the quarrier, the file-maker, and, notably, the earthenware manufacturer, have all a much higher death-rate; indeed, we have to go to the occupations which are recognized as the most healthy to get a close agreement with the coal-miner.

In drawing attention to the high death-rate in miners from diseases of the respiratory system as compared with that from phthisis, Dr. Ogle refers to the somewhat loose way of certifying death, and expresses the

TABLE II.—COMPARATIVE MORTALITY OF MALES IN ENGLAND AND WALES, FROM 25 TO 65 YEARS OF AGE IN DIFFERENT OCCUPATIONS FROM ALL AND SEVERAL CAUSES, 1880-81-82.

Occupation.	Comparative Mortality from All Causes.	Diseases of the Nervous System.	Phthisis.	Diseases of the Respiratory Organs.	Liver Diseases.	Other Diseases of the Digestive System.	Alcoholism.	Accident.	All other Causes.
Clergyman	1,000	180	116	116	28	49	4	11	496
Physician	2,018	334	222	250	183	74	25	84	846
Farmer	1,135	146	185	178	74	54	11	54	433
Agricultural labourer ...	1,261	144	219	281	36	77	2	59	433
Gardener	1,077	113	218	200	32	40	4	43	427
Fisherman	1,433	146	194	162	58	62	7	273	531
Commercial traveller ...	1,705	250	432	264	110	47	41	65	496
Innkeeper	2,736	360	531	390	432	67	99	81	776
Grocer	1,387	192	300	209	94	56	18	25	493
Draper	1,588	196	541	232	63	68	14	41	433
Butcher	2,104	250	470	375	173	59	41	63	673
Baker	1,723	245	381	334	83	47	27	38	568
Tailor	1,890	259	513	335	86	76	20	32	569
Shoemaker	1,658	219	457	282	58	54	7	31	550
Printer	1,926	162	829	299	50	58	5	43	480
Earthenware manufacturer	3,133	252	851	1.160	88	61	14	43	664
Wool manufacturer... ...	1,856	228	462	369	65	72	7	49	604
Mason	1.743	158	453	362	54	61	9	81	565
Plumber	2,162	300	442	333	86	68	22	131	780
Carpenter	1,475	160	367	239	65	54	7	68	515
File maker	2,998	471	779	629	74	58	5	11	971
Blacksmith	1,750	171	388	367	56	63	14	88	603
Miner, Durham and Northumberland...	1,570	158	243	219	59	61	7	353	470
All males, do.	1,723	205	320	279	65	74	23	176	581
Miner Lancashire	1,671	149	225	412	32	58	5	356	434
All males, do.	2,246	255	450	552	76	81	31	147	654
Miner West Riding ..	1,388	108	200	309	38	56	2	290	385
All males, do. ...	1,854	212	423	383	67	70	13	113	573
Miner, Derby and Nottinghamshire	1,320	115	212	248	31	61	7	293	353
All males, do.	1,522	178	299	266	74	59	16	118	512
Miner, Staffordshire ...	1,671	146	183	468	36	50	2	309	477
All males, do. ...	1,811	210	313	406	77	70	16	135	584
Miner, South Wales and Monmouthshire	1,944	108	299	527	43	63	9	412	483
All males, do.	1,809	174	363	376	67	70	13	221	525
Mean for coal-miners ...	1,603	135	227	353	42	58	5	338	445
Miner ironstone districts ...	1,500	92	254	371	25	25	14	371	348
Miner Cornwall	3,308	210	1,241	824	72	101	4	210	646
All males, do.	1,595	178	365	297	49	65	7	106	528
Quarrier	2,018	149	554	493	45	68	9	266	434
Hawker	3,379	372	854	755	85	119	34	95	1,065
All males, England and Wales	1,799	214	396	327	70	68	18	121	585

opinion that many deaths registered under the name "miner's phthisis" should really be under one or other of the diseases of the respiratory organs, and that there should be an addition to the number of deaths from the latter and a corresponding reduction in the number of deaths from phthisis. What this addition should be it is impossible to say; but although it were considerable, there are still, as shown in Table II., a number of occupations having a higher death-rate from diseases of the respiratory organs. If, as suggested by Dr. Ogle, an addition should be made to the figures in the column under diseases of the respiratory organs, and a corresponding deduction from those under phthisis, then the latter will occupy a surprisingly low place relative to deaths from that cause in other occupations. As it stands in Table II. there are few occupations with greater immunity from phthisis than coal-mining, and if the figures be reduced we must turn to the very healthiest occupations, such as that of the fisherman, the farmer, and the gardener for an equal comparison.

The comparative immunity of coal-miners from phthisis has been the subject of observation by medical men, both in this country and on the Continent. Dr. Nasmyth* found that in the parish of Beath in Fife-shire, for the twelve years from 1876 to 1887, the death-rate from phthisis was 1·01 per 1,000 for miners, as compared with 1·72 for females and 1·33 for both sexes. The opinion has been firmly expressed by at least one Continental writer† that the coal-dust inhaled into the lungs by the coal-miner has a preservative influence, and to some extent prevents consumption. An examination of coal-dust under the microscope shows that the particles are rounded, and on that account much less likely to irritate the lungs than the heavier and more angular dust made by the mason and the quarrier.

The death-rate of coal-miners from alcoholism is particularly low, which goes to show that the occasional drinking to excess indulged in by many of them is less deleterious in its effects than the more frequent tippling of men in some other occupations.

In comparing the figures for the six several coal-mining districts, one is met with differences the cause of which is not apparent. South Wales and Monmouthshire have a much higher death-rate than any of the others, and this suggests the enquiry, what relation will Scotland bear to these districts? The workings of the collieries in Scotland being in general not so extensive nor so deep as those in England and Wales, it is probable that, on the whole, the underground air is purer, and the

* *Trans. Min. Inst. Scot.*, vol. x., page 161.

† *Arbeiter-Schutz*, by Dr. Hirt, 1879, page 19.

extremes of temperature not so wide in Scotland as in England and Wales; and it may be safe to assume that the average figures of the six coal-mining districts already referred to will form a fair basis for the mines of Scotland.

Because of the very favourable aspect in which the figures on Dr. Ogle's table place the coal-miner as compared with men in most other occupations, we are disposed to criticize his table with the view of finding out whether the method of compilation is sound. A few objections may be mentioned, some of which Dr. Ogle has anticipated and answered.

It is obvious that, to a certain extent, coal-miners are picked men. Those who are lame, blind, and otherwise infirm, will not choose this occupation; and those who by accident are disabled for active exertion must leave it. For these reasons the figures in the table will tell too favourably for the coal-miner, seeing that the population, as a whole, includes all infirm persons. But the same may be said of several of the occupations named on the table, such as quarriers and blacksmiths, and yet these have a higher death-rate than the miner.

The death-rate from accident being so high in the coal-mining occupation, there must be a corresponding decrease in the number of deaths from natural causes. To this extent the table shows too favourably for the miner from a health point of view; but, as has already been noticed, the deaths from all causes, including accident, are in the case of coal-miners less than those of most other occupations enumerated in the table. Moreover, we have seen that the deaths from accident have been proportionally much reduced during the last forty years. The small error due to this cause must, therefore, be of less account in each succeeding census.

Another point that suggests criticism is, regarding the period of life embraced in the table. A coal-miner has ten years of his working life past at the age of twenty-five, and many leave pit-work before the age of sixty-five. It may be answered, however, that whilst that is so, the same may be said of other workers mentioned in the table; and that on the whole, especially with those industries with which one would most readily form a comparison—that is, labouring occupations and trades,—they are substantially on an equal footing.

It has to be borne in mind that no mortality-table can present the facts with absolute accuracy. At the same time there seems no good reason to doubt the general reliability of the table as a statement of relative health conditions.

On the whole, therefore, we have good grounds for regarding the occupation of the coal-miner as one of the healthiest; and even after

including deaths from accident we see that the mortality among coal-miners is less than that of most manual occupations. In the *Report of the Royal Commission on Labour*, 1892, the opinion of the committee on this subject is stated as follows:—

> The weight of evidence seems to be against the idea that coal-mining is an unhealthy occupation, even when allowance is made for the probability that weakly men either avoid or soon abandon it.

There are several circumstances which may be regarded as contributing to the evidence that the health conditions of the coal-miner are favourable.

In the first place, the underground temperature is equable, and on the whole, not uncomfortably high. That these are favourable conditions receives some corroboration from the fact that pit ponies, although confined underground for years, thrive and keep up in flesh and appearance even better than when worked on the surface. The regular temperature of the air seems to more than make up for the want of daylight. No doubt an excessively high temperature, especially if accompanied by a moist state of the air, is bad, but the former is confined to the very deep mines, and a conjunction of the two is not common. The sudden change from one extreme of temperature to another, when the miner comes out of the pit on a winter's day, is what most readily leads to diseases of the respiratory organs, and should be provided against more effectually than is the custom.

In the second place, the bulk of the coal-miners live in rural communities, and have the benefit of fresh air.

Thirdly, the coal-miner's working day is a comparatively short one, and he seldom works every day in the week. The Scottish collier has always had a hankering after a weekly holiday. As far back as the year 1641 an Act of the Scottish Parliament was passed ordaining colliers and other colliery workmen to work all the six days of the week, the reason given being that they had been in the habit of taking frequent holidays, which they spent in "drinking and debauchery, to the great offence of God and prejudice of their masters." Like many other of the early Acts this one was pretty much ignored; at any rate we find that towards the end of the next century five days was the ordinary week's work in the collieries.

Good as things are, we hope to see them better. We cannot entirely do away with all the causes of death and disease, but strenuous efforts are being made to lessen their effects. The composition of the gases met with in mines, and their effect on the human system, are receiving most

careful attention from Dr. Haldane, Dr. Clowes, and others. Ventilation has been brought to a high state of efficiency; the resources of science are taxed to provide an explosive that can be used without the risk of igniting fire-damp, as the labours of the Flameless Explosives Committee show. Better dwellings and improved sanitary arrangements are now the rule. All these are tending towards the bettering of the health conditions of coal-mining.

Mr. MALCOLM (Arniston) mentioned that he had taken a census of the miners in a working where 40 miners were employed, and he found 11 of them whose average age was 74 years.

The PRESIDENT said that he found in connexion with colliery friendly societies that underground workers drew less money than those engaged on the surface.

The discussion was adjourned.

MÜLLER SMOKE AND GAS-MASK.

Mr. DUGALD BAIRD (Acklington) thought that the apparatus would be very useful, and that it would be desirable to have several stored at some central place where they could be obtained at short notice.

Mr. MALCOLM (Arniston) thought that it would prove very useful in the case of underground fires.

Mr. JOHN LOVE (Loanhead) doubted whether the material of the mask was sufficiently fire-resisting.

The PRESIDENT said the apparatus could not be meant to be used in a very high temperature, and he supposed it would suit better for bad air than for heat.

The meeting then terminated.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE INSTITUTION OF CIVIL ENGINEERS, GREAT GEORGE STREET, LONDON, JUNE 4TH, 1896.

MR. G. A. MITCHELL, PRESIDENT, IN THE CHAIR.

The PRESIDENT read the following address:—

PRESIDENTIAL ADDRESS.

BY G. A. MITCHELL.

It is my duty and privilege at this time to deliver to you an address, and in doing so I desire at the outset to express my sense of what a great honour it is to fill the office of President of this Institution. While appreciating the honour of the position, I cannot but feel a sense of the accompanying responsibilities, and I fully realize that not the least serious of the duties is the delivery of a Presidential address at such a meeting as this.

If what is said to you, to-day, is not new, if the subjects dealt with are familiar to you, you must bear with me and remember how increasingly difficult it becomes every year to secure fresh matter for such addresses.

It will be my object in a very general way to bring before you some of the improvements and changes in mining, with special reference to the past forty or fifty years. I choose this period, as the middle of the century is sufficiently remote to show many contrasts with the present, and yet sufficiently near not to be in the region of ancient history.

Many circumstances have had an influence in the production of the improvements and changes, and, among others, largely the following:—(1) Government legislation, accompanied with the appointment of inspectors of mines; (2) the spread of education and knowledge among

those engaged in mining; (3) the establishment of mining societies, with the facilities afforded thereby for the publication of information, and for the discussion of matters affecting mining in its different branches.

The influence of inspectors of mines was very great indeed during the early period when they were first appointed. They were men of intelligence and experience, and, in reading their early reports, we cannot but be struck by their patient and persistent endeavours to call attention to the improvements, desirable and necessary for safety and economy. Their work was at first carried on against much opposition, but this opposition soon disappeared, except in a few cases, and it came to be recognized that their labours resulted in much good to the whole mining community. The increase in the knowledge of colliery managers, and the establishment of mining institutes which have been productive of so much good, were, as is well known, largely the result of mining legislation and the appointment of inspectors.

When we attempt to investigate the details of mining arrangements in use about fifty years ago, we are, at the outset met with the difficulty that the knowledge of mining science was very much greater in some districts of the country than in others. This makes it far from easy to obtain information regarding the position of matters at the time. The North of England, for example, was far in advance of other districts, and a description that would apply to a North of England colliery, would be very far from being applicable to, for instance, a Staffordshire colliery. The difference between districts was then very much more marked than it is at the present time.

Recognizing this difficulty, I do not intend to attempt to speak to you of many of the details in connexion with colliery arrangements, but to deal only with a few important points in which there has been a marked change for the better, over the whole country.

Perhaps there is nothing more important about a colliery than the ventilation of the workings. It is now almost a truism to say that good ventilation is not only a just and reasonable demand on the part of the miners, but is also an actual benefit to the owners, as men cannot do the same amount of work in defective air as in a good atmosphere. Forty or fifty years ago the desirability, from all points of view, of having workings well ventilated was not fully recognized. In reading the reports of inspectors of mines in the early days, we are struck by their numerous allusions to defective ventilation, and we are also surprised to note the opposition that they encountered at times in their efforts to get matters improved. They gradually overcame this opposition, largely by

being able to convince the owners of the advantages of providing good air. One of the inspectors, Mr. Herbert Mackworth, inspector for the south-western district, in his report for 1853, states that colliers have admitted that, with improved ventilation, they can do one-fourth more work, and the same inspector, in his report for 1854, gives a striking example of the disadvantage, financially, of bad ventilation:—"At the United mines in Cornwall," he says, "the temperature of one of the levels was 105 degs. Three gangs of miners relieved one another every five minutes, and to cool themselves plunged into water eight or ten times a day. The level was costing £18 per fathom." A simple arrangement was suggested for improving the ventilation, and when the alteration was made the temperature was reduced to 80 degs, and the cost of driving the mine was reduced from £18 to £5 per fathom.

The principle of splitting the air-currents and carrying the air, on the best system, through the different parts of the mine, was well understood in most districts. At the more important collieries, furnaces and steam-jets were in use with more or less satisfactory results, but, in many cases, reliance was placed on natural ventilation, which was quite inadequate to produce a sufficient current. The first volume of the *Transactions* of the North of England Institute of Mining and Mechanical Engineers, 1852–53, is practically entirely devoted to the subject of ventilation, and much is said of the comparative advantages of the steam-jet and furnace. The discussion regarding the merits of these methods was due partly to the fact that several parliamentary committees had recommended strongly the use of the steam-jet in place of the furnace. This was specially the case in 1839, 1849, and 1851. It became evident that the recommendations were made without sufficient knowledge, when the comparative merits of the steam-jet and of the furnace came to be experimentally investigated, the latter being found to be immeasurably superior to the former.

In the various discussions at this time very little is said about mechanical ventilation, although the principle had long been understood. As far back as 1556, Agricola in his book *De Re Metallica*,* gives descriptions of several forms of fans and mechanical ventilators, many of them crude in form, but differing little in principle from the various forms of fans, etc., of the present day. About the end of the 18th and beginning of the 19th century several patents were taken out, one for example by Mr. William White in 1789, in which he described a fan-wheel

* *Report of the Commissioners appointed in 1864 to enquire into the Condition of all Mines in Great Britain*, Appendix B, page 278.

revolving in a case, the foul air being admitted at the axis, and expelled at the periphery. It is probable that it was on account of their supposed unreliability that such ventilators were so long in coming into extensive use. We find the fear of their breaking down referred to by Mr. Matthias Dunn in 1844, and by Mr. John Hedley in 1851. The first ventilator introduced to any great extent was the Struvé, for which a patent was taken out in 1846. A paper was read before the British Association in 1848, describing the arrangement, and subsequently it was introduced at various collieries. It consisted of two large chambers moving up and down in water contained in a tank, so as to form a double pump. It seemed to work fairly well, and one is described as capable of passing 40,000 cubic feet of air per minute.

For the ten years from 1844 to 1854 many patents were taken out in connexion with the ventilating of mines. One inventor, for example (Mr. James Grant, in 1844), proposed that steam pipes should be made to circulate round the workings, with here and there "trumpet-mouthed openings for the collection of the noxious air by means of the current of steam." This is only one example of many which showed great ignorance of the principles involved.

These principles are now, I need hardly say, among the elements of mining science, the only difference of opinion being as to which is the best form of ventilating appliance, and any one of those in use gives good results. The quantity of air now passing through our mines on the average, in consequence of the attention paid to ventilation, is greatly in excess of what was considered necessary forty or fifty years ago.

To the improvements in ventilation, in conjunction with the improvement in the construction of safety-lamps, is largely due the decrease in the number of fatal accidents from explosions. The death rate per 1,000 persons, due to explosions of fire-damp, was 1·280 in 1851-55, and 0·281 in 1891-94, which shows a remarkable change for the better.

Unfortunately, we have still to deplore the occurrence from time to time of serious explosions accompanied with great loss of life, and unhappily there have been several such disasters during the past few months. We must express the most sincere sympathy for all who have any connexion with the collieries concerned, or who are interested in any way in the men who have so unhappily lost their lives. We look forward, not without hope, to the time when such disasters will be unknown.

To the improvement in ventilation we may trace the great improvement in the health of miners. Mining, forty years ago, was a very

unhealthy occupation. This cannot be more strikingly shown than in an extract from a report published by the Oddfellows' Society, and quoted by Mr. Herbert Mackworth, H.M. Inspector of Mines, in his report for the half-year ending 31st December, 1854, which is as follows:—"This class of lives show a very large amount of sickness at every period, and an increased sickness with the advance of years. From the very nature of the employment this must have been anticipated, but not to such an extent as appears in these results. At age 20, miners experience an average sickness of 46 per cent. more than the general class, at age 30 they have 70 per cent., at 40 years 78 per cent., at 50 years 76 per cent., and at 60 years 53 per cent. more average sickness than the general class of lives." Mr. Mackworth also states that the average number of years during which agricultural labourers of Great Britain continue to work, taken from the census returns of 1851, was forty-two years four months, and of colliers 28 years 6 months. Mining, now, instead of being as it then was, one of the most unhealthy of occupations, is one of the most healthy. For instance, we find from tables* of the comparative mortality of males from 25 to 65 years of age, in different occupations, in 1880, 1881, and 1882, that the mortality of miners is 1,603, as compared with an average of 1,799 for all males in England and Wales, even including accidents, and if we exclude accidents, "the mortality of coal-miners only slightly exceeds that of the most healthy class of men—the agriculturists, that is to say, the farmers, the agricultural labourers, and the gardeners." This changed state of matters says much for the immense improvement in the condition of mines, specially as regards ventilation. As a matter of fact, the air in coal-mines is better than in many factories.

In the various details of the conveyance of coal from the working-face to the surface there has been great progress since the middle of the century. It is difficult to believe that, as late as 1843, the bearer system was still in existence in the East of Scotland, in connexion with the edge seam workings, but such is the case. It was in this year that female labour in mines was abolished, and we know from the reports that many of the females were employed in carrying coals, to the surface, in baskets, on their backs. This degrading method of conveyance was not common, but in many collieries the arrangements were crude and antiquated. Baskets were filled at the working-face, and after being dragged to the main roads, were lifted on to wheeled carriages by means of cranes or

* *Royal Commission on Labour*, October 27th, 1892, Dr. Ogle's evidence.

otherwise, and taken to the shaft-bottom. From these carriages the baskets were swung on to chains or ropes and conveyed up the shafts. Horse gins were still used for winding in some places. Where steam engines were in use, sometimes a single engine was used for winding from as many as six shafts. This was notably the case in Staffordshire, and was the cause of many accidents. Guides in shafts were by no means universal, and cages were not always used.

Perhaps the development of the winding arrangements for shafts is as interesting as any change dealt with in the history of mining appliances. There has been a gradual evolution, and the improvements have been largely called forth by the necessity for greater facilities to cope with increasing outputs. The various stages in the evolution from an early time may be given as follows:—Hand windlass or gin. Horse gin. Gin worked by natural water-power. Gin worked by water-power, pumped up for the purpose by a steam-engine. Winding-drum coupled direct to steam-engine. Automatic arrangement for slowing the baskets when passing each other in the shaft, to prevent collisions, rendered necessary by the increased speed of winding. Guides as a more effective arrangement to prevent such collisions. Cages to convey the hutches to the surface. Improved winding-engines. It is sufficient to name these stages in the improvement of winding arrangements without entering into details.

About fifty years ago there seems to have been special activity in the efforts to provide facilities for winding large outputs, and we find some very curious proposals in the patent lists of the period. For example, there are several patents for raising and lowering in a vertical tube in the shaft by means of atmospheric pressure, one of these being by Messrs. James Knowles, Jun., and A. B. Woodcock, in 1845. In this it was proposed to propel a piston in the tube by exhausting air from the top, the cage being suspended by rods from the piston, the top of the tube being sealed. The lowering was to be effected by allowing air to pass in through a valve. Another patent, taken out in 1846 by Messrs. George Hinton Bovill and Robert Griffiths, is even more curious. Two connected vacuum-pipes placed in the shaft have longitudinal slits covered with air-tight, flexible diaphragms. The pistons in these tubes carry "wheels which, being of larger diameter than the tubes, bulge outwards the diaphragms, and support between them the platform on which the load is placed." By means of an air-pump the air above the piston is exhausted, and so the load is raised, or the load is lowered by admitting air above the piston.

The period seems to have been rather crazy, generally about pneumatic arrangements, as we find applications proposed for pumping and for many other purposes.

Perhaps the invention which, as much as any other, assisted in the improvement of winding facilities was that of the wire rope. The cost of hemp ropes for deep shafts was very serious, and often required 4d. to 6d. per ton of output to uphold them when baskets were used. We are told that the Wearmouth colliery ropes cost £550 per pair, weighed 5¾ tons, and only lasted for ten months. Iron-wire ropes began to be used first about fifty years ago. We find that, in 1846, the miners of Wingate Grange colliery resisted the introduction of iron-wire ropes and refused to work. They raised an action for the recovery of their wages, but the case was decided against them. The use of iron-wire ropes very quickly gained ground, and they have in turn been replaced by steel-wire ropes.

Fifty years ago and for many years after, the arrangements for treating coal at collieries were very primitive. In many cases the coal was taken off the cage or off the chain, and drawn by a horse to the heap or bin from which the coal was lifted for the market. The introduction of improved screening-and-picking arrangements and of washing-machinery, has been of comparatively recent date. A plate picking-band, which, I believe, was the first of the kind, was patented by Mr. Thos. Whitelaw, of Motherwell, in 1877. This form of band is still largely in use, and there are now various other forms of picking arrangements common in all districts. It is unnecessary for me here, before practical men, to speak further of arrangements of this kind, which are well known to us all, but let me remind you that, now, every care and ingenuity is devoted not only to the preparation of coal for the market, but also to the economical handling of outputs. At a colliery visited by our members recently, we were told that, by the remodelling of the pithead, the wages of 30 men had been saved.

The difference between the systems of underground workings now and those of fifty years ago, is, perhaps, not so great as we might anticipate. All or almost all forms of workings now in operation were common in the past in various districts, but there is now, perhaps, less rooted prejudice in favour of any particular system, and more effort devoted to choose the system best suited for special conditions. It is true that there is still a want of scientific accuracy in some directions, and that there is still a great deal left to custom, the particular form of working in use

being adopted in many cases without any special reasons, and merely because it has been formerly in use in the district for the same seam. Notwithstanding this, workings are better conducted now than formerly, and, even where the same general system is adopted, the details are more carefully considered. As a proof of this there is very much less coal lost than in the past. It is not more than forty years since the working of thick seams in both English and Scottish coal-fields was carried on in such an unscientific manner that practically only the coal in the first working was got, the stoops, or 40 or 50 per cent. of the whole coal, being entirely lost. Such a state of matters would not now be permitted.

It is unnecessary for me to refer further to the details of coal-mining in which progress has been made. There have been great changes. Now we have deeper shafts, larger fittings, better pumps, better boilers, better everything.

In speaking of the position of mining now, however, compared with that of forty or fifty years ago, we must take care not to fall into the mistake of imagining that we have reached something like perfection, and that great improvements in the future are unlikely. If we read the records of the past we find constant references to improved machinery and appliances. Among others, Mr. Bald in 1808 and Mr. Matthias Dunn in 1848 made such references, and the latter speaks of what would now appear rather a primitive arrangement as the "acme of perfection." The history of mining tells us of a constant, gradual progress, and we must remember the past and believe that, as it has been, so it probably will be. Our successors in the next generation will doubtless look upon many of our arrangements as clumsy and antiquated. We can more readily believe this if we consider the extraordinary activity in scientific discovery during the last few years. We have been startled by the discovery of a new constituent in atmospheric air, the analysis of which was considered to be so well known. That chemists should in the past have failed to discover argon, this new gas, appears almost incredible. We have been even more startled by what is perhaps the greatest discovery of modern times, that of the Röntgen, or X rays, as they have been called, a discovery which is likely to prove of immense direct value to medical science, and which may lead to an extension of our general scientific knowledge. In an article in the *Quarterly Review** on the subject, the writer says, "Lord Kelvin anticipates unhesitatingly the establishment of a general theory which shall include light (old and

* 1896, page 506.

new), old and new knowledge of electricity, and the whole of electro-magnetism; and the approaching disclosure can be foretold of a more profound correlation of the physical forces than can at present be distinctly apprehended." With the history of such discoveries before us we can well believe that there is no finality in mining science, and we can safely predict improvements in machinery and appliances, and we can believe that, in the future, there may be not only further consolidation of knowledge but important new inventions and discoveries.

We have already had some foretaste of great changes in the introduction of electric machinery, which has made such headway during the last few years. Fifty years ago the electric telegraph was in its infancy, and there was no thought of the use of electricity for the transmission of power. Now, as all know, it is very largely used for industrial purposes, and specially for mining appliances. We may look forward to great improvements in dynamos and motors. Great advances have already been made in their construction, and they are more reliable in many ways now than they were even a few years ago.

During the past year a new form of motor has been much spoken of —the polyphase motor, as it is called. These motors have been known to electricians for a considerable time in this country, but, although they have been in operation on the Continent and in America for some years, it is only very recently that they have been introduced here to any extent. They have some points which make them very suitable for adoption in coal-mines, such as the absence of brushes. There are also some drawbacks to their successful adoption meantime, notably the extra power said to be required to start them under load. It is probable that the defects which they possess will be remedied in time, but whether or not they will displace direct-current motors in the future, it is impossible to say. That they will do so where power has to be transmitted for long distances is probable, as high-tension currents can be used, the voltage being reduced by the use of transformers where desired.

Familiarity with electrical transmission of power will probably lead to many changes in the future, and, among others, to the more extensive use of coal-cutting machines. Coal-cutting by machinery has not, in this country, been a great success in the past, notwithstanding periods of activity in the introduction of coal-cutters from time to time, for many years back. In America, on the other hand, they have, during recent years, been making great headway. It is stated, for example, that in the

State of Illinois last year, with a total output of 17,735,000 tons, 3,531,000 tons were produced by 322 machines. From my own experience with such machinery, I am convinced that the want of success in the past has been due to failure in designing machines suitable for the work to which they have been applied. One cause of comparative failure probably is that machines have been made too heavy for general use. As hitherto made, they are only suitable for workings where they seldom require to be shifted from one place to another, as in longwall workings, in clean fields, with strong roofs. If we could get lighter machines more easily handled, even if they were not capable of so much daily work, it is probable that they would be much more extensively adopted, especially if driven by electricity, which is not only more economical as a power, but also much more convenient than compressed air.

By the use of coal-cutters many thin seams should become workable that have in the past been neglected. It is possible that in the future it may be to the opening up of thin seams, worked by coal-cutters, that we must look for the maintenance of outputs in some districts. There are districts in which there has been in past years a great increase in output, where the limits of the coal-fields are well known, and where such increases cannot continue. This is notably the case in the Lanarkshire district of Scotland. There, there may be a further increase of output for a few years, but after that there must be a decrease unless the output can be maintained by the working of thin seams, of which there are a number available, and only partly worked. The production of large outputs from these seams will be difficult without the use of coal-cutting machines: with coal-cutters the output may be long maintained.

The experience of the past should teach us to be very careful about prophesying the exhaustion of coal-fields. Ludicrous mistakes have often been made in this way. As far back, for instance, as 1555, there was an alarm that the coal in Scotland would be quickly exhausted, and an Act was passed in 1563 restraining the export, and the same provision was repeated in subsequent years on more than one occasion. In 1609, the reason given for confirming a former Act is "the haill coill within this kingdome sall in a verie schorte tyme be waisted and consumed."* Such an exhaustion is fortunately for Scotland yet somewhat distant, and, unfortunately, our trouble at the present moment for the United Kingdom is that too much coal is being produced, and that there is depression in the coal-trade in consequence.

* *Act Parl. Scot.*, vol. iv., page 408.

It is interesting to notice in the literature of the coal-trade how frequently reference is made to periods of depression, and it is not only interesting but comforting, because, if our complaint of bad times is nothing new, we may hope that the present depression will pass away, as others have done in the past.

The miners of this country have had from early times, during these periods of depression, their own ideas about putting things right. About fifty years ago the theories that were being promulgated were very much the same as those which are producing such uneasiness in coal-trade circles at present. The men were bent on combination and restriction as a cure for the evils of the time, and they aimed at a minimum wage, as they do now. We find that in 1847, Mr. John Hall, secretary to the Miners' Association, said:—"If a period arrives when trade is bad and the demand for coal declines, we propose to keep up the colliers' wages by regulating the supply and keeping coal dear, so that they will still earn, say, 3s. 6d. a day for a less quantity of coal."

In the report of the Commission, appointed in 1844 to enquire into the state of the population of the mining districts, in which the quotation just given occurs, the prevalent restriction is much spoken of and its folly pointed out.

Few who have made a thoughtful study of the subject believe that combinations and restrictions can keep up prices and wages for any lengthened period of time when they would naturally fall. It is clear that they have never done so in the past, and history will doubtless repeat itself. Even Parliament could not permanently fix prices. It is, perhaps, little known that this has been tried, but such is the case. The Privy Council of Scotland in 1621 enacted that the price of coal was to be fixed at 7s. Scots per load, and subsequently at 7s. 8d. on certain owners objecting to the price fixed. Needless to say, the attempted regulation was not long continued. I understand that there was some legislation in England also of the same kind.

It is unfortunate that trade is hampered so often by disputes between masters and men. Many of these arise from the desire to force on changes in the conditions of employment, some of which may come gradually, but can come in no other way. Miners appear not to realize in what an immensely better position they are than those who preceded them. The quotation which I have given of the remarks of Mr. Hall illustrates this. He contended for a minimum wage of 3s. 6d. The leaders of the present day also ask for a minimum wage, but of nearly twice this amount. It may be that the time will come when the wage

will never fall below 6s. or 6s. 6d., and, if so, we shall all rejoice, but it is quite evident that that time has not come yet.

As illustrating the improvement in the conditions of the employment of miners, mention may be made of a fact in the history of mining in Scotland which may be new to some here. Until an Act was passed in 1775, not really taking effect until 1799, miners in Scotland were practically slaves. No collier was permitted to remove from one place to another without special permission from his employer, and no person was allowed to engage a collier without a certificate from his previous employer showing a reasonable cause for the removal. If a collier deserted, his employer could claim him within a year and a day, and he had to be given back at once under pain of a fine of £100 Scots. The deserters were liable to be punished as thieves. It is difficult to realize that such a state of matters could exist less than 100 years ago.

It is unfortunate that the present time should be chosen for an agitation for a minimum wage, when the outlook for the coal trade is so unpromising. Foreign competition both in the coal-trade and in the iron trade is keener than it ever has been, and extraordinary efforts are being made by Continental countries to take our trade from us. Foreign competition is nothing new. We find, for instance, in the *Mining Journal* of 1848, a reference to the importation of rails or railway-bars, as they were then named, from America, and in a Parliamentary Report for 1847, we find statistics of the competition of Germany with Sheffield and Birmingham in cutlery. The competition has become intensified, and is not now confined to a few special manufactured articles. Germany and Belgium especially are competing with us in many markets in the coal and iron trades. The position as regards the iron trade has been brought home to the British public in the *Report on the Iron and Steel Industries of Belgium and Germany*, presented by the delegation organized by the British Iron Trade Association. In this Report there is much instructive reading.

Some attention is given to the question of shipping freights and railway rates, and since the issue of the *Report* there has been much discussion regarding these matters. It is stated that until quite recently the P. and O. Steam Navigation Co. carried goods from Antwerp to Bombay or Calcutta *via* London at 10s. per ton, whereas the freight for similar goods of British manufacture from London was 15s. 9d. in the same steamers. It is difficult to understand how such rates can be justified, and it is certain that they have seriously interfered with

shipments from this country. I am informed that, at the present moment, it costs 6s. 4d. per ton more to convey manufactured iron from Glasgow to Bombay than from Antwerp.

In dealing with railway rates it is shown that iron and steel are conveyed in Germany and Belgium, at rates which are about one-half and one-third of those charged in this country for similar distances.

It is with some hesitation that I refer to the question of railway rates. It is a question of great difficulty, and one which can only be properly handled by an expert, as in the fixing of rates there are very many circumstances to be considered. It may be fairly said, however, that our manufacturers and producers have a right to expect assistance in their efforts to hold their markets, and that it is both for the interest of the public and of the railway companies themselves, that reductions in rates should be granted where possible. If railway rates must eventually be reduced, the reduction should take place before, and not after, the trade is lost.

There is at times a cry for State ownership of railways on the ground that such would lead to economy and to the granting of greater facilities, but it is maintained by many authorities that experience has shown this not to be the case, and that railways thrive better and serve the public better when worked as private concerns. If this be a correct conclusion, it is probably also the case, that it is not desirable that the Government should deal too strictly with rates, which are naturally best fixed by those who are in contact with all the facts. At the same time, if managers of railway companies rest in the security of arrangements with other companies, and do not give the facilities required to stimulate trade, the traders may be compelled to call for further control. It cannot be denied that there are defects in our railway system. There ought to be, for instance, more interchange of traffic, on reasonable terms, between different railway companies, and more reckoning of distances on several railways as if only on one. It appears unfair, for example, that, if a railway company possesses the only access to a dock with shipping facilities, that it should have the power of fixing prohibitory rates for goods from other railways.

That the Government seems to recognize this is shown in the case of the Bo'ness dock. When this session the North British Railway Company applied to Parliament for liberty to purchase the dock, it was laid down as a condition that coal from collieries on the Caledonian railway should have advantage of the same rates as from collieries on the North British railway. Rather than grant the terms, the North British

Railway Company stated that they would not proceed with the Bill. Railway companies ought to recognize that the time is past for such monopolies. They will, if wise, face the increasing difficulties of the situation, and give rates which, with a due regard to the cost of transit, are sufficiently low to encourage business.

We have been hearing much lately about motor-cars, or horseless carriages, and it is anticipated by some that these may, in the future, compete successfully with railway companies for short-distance traffic at least. The attempt to introduce motive power on common roads for the conveyance of passengers and goods is not new. In the literature of fifty years ago there are many references to steam carriages. Patents were taken out, and one company is spoken of as being formed with a capital of £200,000 in connexion with the improvements designed by Sir James Anderson, Bart. Many carriages were run, and run successfully, and everything seemed to point to a rapid development. It is probable that they would not have so completely disappeared from use except as represented in late years by the clumsy traction-engine, if it had not been for the vexatious legislation by Government, and the vexatious restrictions put on their use by public bodies. The history of the treatment given them has been little short of a disgrace, and it is not complimentary to the English nation that Continental countries have been so far before us in the adoption of such carriages. The proposed Act being considered in Parliament at present is intended to produce a better state of matters, and it is safe to prophesy, if it be passed, that in a very short period motor-cars for passengers and for goods will be very largely made use of in this country. That they will compete with railways for short-distance traffic is possible. With the use of oil-motors they can be made very light, and easily handled, and where coal, for example, has to be carted from the railway-depot to the consumer, after being conveyed a short distance by rail, it is possible that it could be more cheaply conveyed by motor-cars the whole way from the colliery. Whether this competition take place or not, it is practically certain that there will be established a new and very large industry.

In my address I have spoken specially of coal-mining and of subjects relating thereto, as those in which I am directly interested, but our Institution does not confine itself to coal-mining subjects. During the last few years we have had an increasingly large number of papers on gold-mining and on the treatment of ores, and some of these papers have been of very special interest. The energy expended in the search for

gold during recent years has, perhaps, been unparalleled in the world's history. One notable feature in the gold-mining of the present day, especially in South African mining, is the establishment of the industry on a scientific basis. The very best engineering and chemical knowledge has been devoted to the devising of economies in the production and treatment of ores, and to the invention of processes whereby the largest possible amount of gold may be extracted from the ore. One invention —that of the cyanide process (MacArthur-Forrest patent)—has practically revolutionized gold-mining in South Africa and New Zealand, and is also exerting a great influence on the treatment of ores elsewhere. Generally, it may be said that gold-mines are very much more efficiently managed than formerly, and as a result, it is probable that for many years to come the world's output of gold will be very largely in excess of what it has been in the past. Papers on gold mines, and on correlative subjects are of increasing interest to us all. We are to have several before us to-day, and we look forward to many more on gold-fields and gold-mining.

There are many other subjects which engage our attention at the meetings of our local institutes and of The Federated Institution of Mining Engineers, and too much cannot be said of the value of such means of spreading information. The papers that are read, and the relative discussions, record from time to time what is known concerning the many varied problems which engineers encounter in their work. The consideration of these papers assists us in keeping up with the knowledge of the day. Such knowledge daily increases, and increases not so much by the making of great discoveries, as by the intelligent application of known principles to the different departments of mining. There are many different fields, and there is an opportunity for us all to take some part in the improvements which will come. The *Transactions* in the future, I hope, will bear witness to much ability, intelligence, and honest work on the part of the members.

Prof. HULL (London) moved a vote of thanks to the President for his admirable address. It dealt with mining in all its branches, particularly coal-mining, giving an account of the various processes, and of the improvements in mining machinery, and it also went out into the wider field of gold and the other metals.

Mr. THOS. DOUGLAS (Newcastle-upon-Tyne), in seconding the vote of thanks, said that there were few mining engineers present who were older than himself in the profession, for he had only been connected with it for fifty years. But as it was fifty years ago since he entered the profession, he had listened with particular interest to what the President had said that day about the mining operations of that time, and looking back over that half century he could testify to the enormous progress which had been made in the science of mining. But there was very much yet to be done. He regretted that more had not been done in the way of excavating coal by mechanical appliances, and he thought that the members had reason for regret that greater strides had not been made in that direction. Electricity would assist very materially in the future, not only in the excavation of coal but in removing it to the surface.

The motion was enthusiastically adopted, and briefly acknowleded by the PRESIDENT.

Dr. JOHN S. HALDANE read the following paper on "Investigations on the Nature and Sources of the Suffocative Gas met with in Wells: together with Further Observations on the Black-damp of Coal-mines":—

INVESTIGATIONS ON THE NATURE AND SOURCES OF THE SUFFOCATIVE GAS MET WITH IN WELLS: TOGETHER WITH FURTHER OBSERVATIONS ON THE BLACK-DAMP OF COAL-MINES.

By JOHN S. HALDANE, M.A., M.D.,
Lecturer in Physiology, University of Oxford, and Grocers' Company Research Scholar.*

The writer's attention was first directed to the suffocative gas of wells by a newspaper account of an accident which had occurred in a well at Redwick, in Gloucestershire. It appeared that some men had been engaged in the morning in repairing a well about 40 feet deep. While descending the well in the afternoon, for the purpose of bringing out a ladder which had been left behind, one of them was suddenly overcome by foul gas and fell. A companion, who went down to assist him, met with the same fate. A policeman then gallantly descended with a rope round his body, and succeeded with great difficulty in rescuing one of the men, who was still alive. The other was dead.

On the day of the writer's visit to the place, some months later, a light inserted through an opening in the stone covering of the well was at once extinguished. After the stone had been removed a sample of the gas was obtained from the bottom of the well with the help of an aspirator let down by a cord, and so arranged that the tap could be opened by means of a spring, which was released by letting down a weight which ran on the cord. The aspirator drew a large volume of air through a small, dry glass bottle, with a doubly perforated stopper, and the latter was provided with a mercury valve, so arranged as to prevent the access of air or escape of gas after the aspiration had ceased.

The sample from the bottom of the well was found to contain about two parts of air to one of a mixture consisting of 95·80 per cent. of nitrogen (including argon) and 4·20 per cent. of carbonic acid. After a second sample had been taken, a candle was found to burn as much as 4 feet down the well. Air sucked up by a pipe from 8

* The writer is indebted to Mr. A. Mavrogordato, of Trinity College, Oxford, for much assistance in the investigations of the gas in wells.

feet down had no appreciable action when breathed for a few minutes. An upright lighted candle was afterwards let down very slowly, and a sample of air taken opposite the place where the flame was extinguished. This sample contained 17·19 per cent. of oxygen and 0·90 per cent. of carbonic acid.

It is generally stated that the choke-damp of wells consists of carbonic acid. The result of the analysis of the Redwick sample was therefore very surprising. The amount of carbonic acid present was so small that the calculated specific gravity of the pure "choke-damp" was about 0·50 per cent. less than that of air. This accounts for the gradual clearing of the well when the stone was removed. The analysis was made in March, when the temperature of the well would probably be slightly above that of the outside air. The accident occurred on August 2nd, when the well would be cooler than the outside air, so that natural ventilation of the well would not occur so readily.

The examination of this well did not explain why it had been clear when the men were first working in it, and was, nevertheless, in such a dangerous condition in the afternoon of the same day. Further light was thrown on this question by the examination of another well near Balcombe, in Mid-Sussex. This is a large deep well which affords a supply of pure water to several villages in the district. In the sinking of the shaft a borehole had first been made, and during the operations, when the shaft had only been sunk a short distance, two men had been suddenly overcome and suffocated. The accident had occurred in a similar way to that at Redwick, the gas having issued without warning, apparently from the borehole. The bodies when recovered seem to have presented the appearance of intense venous congestion of the face, etc., characteristic of acute asphyxia from want of oxygen.

An engine-house is built over the shaft, and a fan is employed to keep the well clear when men have to descend. The engineer in charge told the writer that the air of the well frequently became foul, especially when the weather was bad. The foul gas sometimes streamed up into the engine-house, so that the engineer was unable to enter with a light in the morning until the door and windows had been opened. He also told the writer that a slight blower of gas sometimes issued from a hole in the side of the shaft. This at once suggested that the outflow of gas was due to falls in barometric pressure. An aneroid barometer was left with the engineer, and he was asked to make some notes as to the relation between barometric changes and the state of the well. Unfortu-

nately, excavations were going on almost constantly at the bottom of the well, with a view to increasing the water-supply, and, in consequence, the fan had to be kept working, and it was difficult to obtain satisfactory observations. Nevertheless, it soon became evident that the air remained perfectly clear so long as the barometer was high, and became foul with every considerable fall. It seemed to remain foul for some time during periods of low pressure, and not merely during the fall. To Table I., containing the results of the analyses, notes are added showing the barometric pressure (from the daily weather-charts of the Meteorological Office) at 8 a.m. on the days when the samples were taken. The same table shows that the choke-damp of the Balcombe well contains more carbonic acid than that of the Redwick well.

Several other wells were examined, the most interesting of which was one at Northleigh village, a few miles from Oxford. Dr. Stevenson, of Guy's Hospital, had drawn the writer's attention to a passage in Mr. Plot's *Natural History of Oxfordshire*, published in 1676, in which two accidents from choke-damp are described as having occurred in wells at this village. A sample of gas was obtained from a well about 20 feet deep. The barometer was falling, and the air of the well was foul. The choke-damp present in the air consisted of 93·19 per cent. of nitrogen and 6·81 per cent. of carbonic acid. At the time of a second visit the well was practically clear, the barometer being high and steady. On enquiry, the writer found that there had been an accident at a neighbouring well some years ago; and, probably, a number of fatal accidents may have occurred at this place since 1676.

Table I. contains the analyses of samples obtained from various wells. It will be seen that in several cases the air was nearly pure. In one or two cases where the air, as tested by a candle, was pure the writer obtained evidence that choke-damp was sometimes present, although the persons on the spot were not aware of the fact and could hardly be convinced of the necessity for testing the air with a candle before descending.

The general conditions of formation of the choke-damp present in the wells examined seem to be tolerably clear. During periods of high barometric pressure air is driven into the pores of the strata, through which the shaft of the well passes. Through oxidation occurring in the strata this air is deprived of its oxygen, a certain amount of carbonic acid being at the same time liberated. With a fall of barometer the

TABLE I.

Localities.	Redwick Well. From bottom (38 feet).	Same Well. Second Sample from bottom.	Same Well, 12 feet down. Candle just out.	Balcombe Well, 30 feet down. Candle dim. 19th April, 1895.*	Same Well, lower down. Candle gone out. 19th April, 1895.*	Same Well. 25th April, 1895.* Collected at top.	Same Well. 26th April, 1895. Coming over top. Fan working.*	Same Well. 9th Oct., 1895, 7 a.m.† Collected at top.	Same Well. 9th Oct., 1895, 6 p.m.† Collected at top.	Charterhouse Laundry Well, 4th April, 1895. 115 feet down.	Same Well. 20th April, 1895.	Northleigh Well, 28th June, 1895. From bottom.	Same Well. 12th Oct., 1895. From bottom.	Well at Reading (on 28th March, 1895. From bottom (68 feet).	Another Well at Headington. From bottom (102 feet).	Manhole to Sub-soil drains on Sewage Farm, Oxford.
Composition of sample—																
Oxygen	13·38 13·40	15·13	17·19	18·22	17·61	15·57	14·69	15·52	12·04	19·46	20·53 20·53	14·27	20·52	20·82	20·61	16·04
Nitrogen	85·08	83·51	81·91	79·85	80·17	81·38	82·00	81·88	83·62	79·26	78·96	83·55	79·19	79·13	79·13	80·40
Carbonic acid... ...	1·53 1·54	1·36	0·90	1·93	2·22	3·04 3·07	3·30 3·33	2·61 2·59	4·33 4·35	1·28	0·51 0·51	2·18	0·29	0·05	0·26	3·56
Marsh-gas	0·00	...	...	...	...	0·00	...	...	...	...	...	0·00	...	...	...	0·00
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Otherwise expressed—																
Air	64·07	72·39	82·25	87·18	84·26	74·50	70·29	74·26	57·61	93·11	98·28	68·28	98·18	...	98·61	76·75
Choke-damp { Nitrogen ...	34·42	26·27	16·88	10·92	13·55	22·47	26·42	23·16	38·07	5·64	1·29	29·56	1·56	...	1·16	19·71
Choke-damp { Carbonic acid	1·51	1·34	0·87	1·90	2·19	3·03	3·29	2·58	4·32	1·25	0·48	2·16	0·26	...	0·23	3·54
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Composition of Choke-damp—																
Nitrogen	95·80	95·15	95·10	85·18	85·77	88·12	88·93	89·98	89·81	81·86	72·88	93·19	85·71	...	83·38	84·77
Carbonic acid ...	4·20	4·85	4·90	14·82	14·23	11·88	11·07	10·02	10·19	18·14	27·12	6·81	14·29	...	16·62	15·23
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100.00	100·00	100·00	100·00	100·00	100·00

* 19th April, 1895, 8 a.m., Barometer 29·82, inches. Air of well slightly foul.
20th ,, ,, ,, ,, 30·02, ,, ,, clear.
21st ,, ,, ,, ,, 29·92, ,, ,, ,,
22nd ,, ,, ,, ,, 29·98, ,, ,, ,,
23rd ,, ,, ,, ,, 29·70, ,, ,, ,,

† 8th Oct., 1895, ,, ,, ,, 29·45, ,,

* 24th April, 1895, 8 a.m., Barometer 29·75, inches. Air of well slightly foul.
25th ,, ,, ,, ,, 29·47, ,, ,, very foul.
26th ,, ,, ,, ,, 29·45, ,, ,, ,,
28th ,, ,, ,, ,, 30·00, ,, ,, clear.

† 9th Oct., 1895, ,, ,, ,, 29·05, ,, ,, very foul to-day.

residual gas streams out again, the shaft of the well thus acting as a ventilator to the strata. It seems probable that this process can only occur when the strata are more or less free from water, and at the same time closed above by a somewhat impervious or wet layer. There was no reason to suspect the existence of underground cavities in the neighbourhood of any of the wells examined.

It is well known that falls in barometric pressure commonly cause the issue of gas from old workings or other cavities in coal-mines. Perhaps, however, the extent to which this issue may occur from pores in the solid strata is not thoroughly realized. Prof. Green, of Oxford, kindly directed my attention to a paper* by Mr. T. Fairley, describing a phenomenon which throws a still more direct light on the issue of choke-damp from wells, borings, shafts, etc. In the neighbourhood of Northallerton there exist several so-called "blowing" wells. With a falling or low barometer enormous volumes of air issue from these wells, whereas, with a rising or higher barometer, the current is inwards. Mr. Fairley made a number of observations on the amount of the air-currents into or out of the wells, and on the corresponding variations of atmospheric pressure. He found that a rise in barometric pressure of 0·40 inch caused a total inflow of 12,000,000 cubic feet of air through one of the wells. The outflowing air was practically pure.

It will be seen from the table that, as a general rule, the fouler the air of a well was found to be, the lower was the percentage of carbonic acid present in the choke-damp. This probably indicates that some of the carbonic acid is at first retained in solution or weak chemical combination in the water of the strata, and is afterwards given off slowly when the air becomes less foul.

The wells examined were in different parts of the country and different formations, and it was difficult to say exactly how the air was vitiated in each case. The well at Redwick passed through a layer of peat before reaching the gravel, and oxidation of the peat may have caused the formation of the choke-damp. Balcombe well was sunk through soft, porous sandstone, and the water contained ferrous salts, which were oxidized and precipitated by exposure to air in the reservoir on the surface. Probably, therefore, the choke-damp may have been formed by contact of air with ferrous carbonate. Contamination of the strata by organic matter seemed absolutely excluded. It is worthy of note that the deep wells in the limestone at Headington, near Oxford, seemed to be

* Read before the Geological and Polytechnic Society of the West Riding of Yorkshire, 1881.

practically free from choke-damp. The barometer was very low when the writer examined these wells, so that choke-damp would probably have been met with, were it ever present. The vitiation in the air of the manhole at the sewage-farm near Oxford was doubtless due directly to the respiration of bacteria present in the soil.*

These observations throw considerable light on the risks run by well-sinkers and those engaged in sinking shafts or in other underground operations where candles or lamps are not used. Well-sinkers seem to be usually well aware of the necessity of testing the air with a candle before descending, but they commonly neglect to repeat the test before each descent and at intervals during working. It is evident that a fall of barometric pressure, and consequent outflow of suffocative gas may occur at any time, and cause the utmost danger in a well or shaft which was safe a short time previously. On consulting the *Times* barometric tracing and chart for the day of the Redwick accident the writer found that, as was to be expected, there had been a pretty sharp fall of pressure (from 29·60 to 29·48 inches) between 8 a.m. and 2 p.m. It was doubtless this fall of pressure which had caused the outflow of gas into the well. The barometer had been at about 29·8 to 29·7 inches for several days previously.

If the choke-damp of wells contained more than 12 or 15 per cent. of carbonic acid it would cause marked panting, and thus give warning before it was present in a sufficient proportion to cause danger. Choke-damp of the composition actually found in the wells in which the air was much fouled does not, however, contain sufficient carbonic acid to afford this warning, and the first symptoms experienced would be those due to want of oxygen. Want of oxygen does cause a slight amount of panting, but this is hardly noticeable before the occurrence of dizziness and loss of power over the limbs; consequently, a man descending into the choke-damp as a rule falls off the ladder or becomes unconscious before he is aware of anything being wrong. The symptoms produced by the choke-damp of wells thus resemble those of carbon monoxide poisoning and are, indeed, due to exactly the same physiological cause—a diminished supply of oxygen to the tissues.

For choke-damp such as that described the test with a candle or lamp is well within the limits of safety, and quite reliable if employed suffi-

* The Redwick well is sunk in the alluvium of the Severn valley. The Balcombe well is sunk in the lower Tunbridge Wells Sand, Hastings Beds. The Northleigh well is sunk in the Oxford Clay, and possibly passes into the Cornbrash. The Headington wells are sunk in the Kimmeridge Clay and Coral Rag.

ciently often. As shown in Table I. a candle slowly lowered into the Redwick well was extinguished at 17·19 per cent. of oxygen. In another experiment made in the laboratory, in a small air-tight chamber, in which vitiation by the respiration of a person inside proceeded very slowly, an upright candle went out at 17·57 per cent. of oxygen and 2·82 per cent. of carbonic acid. In another experiment, with black-damp, in Burghlee pit, Midlothian, an open colza lamp, with wick spread out, was extinguished at 17·44 per cent. of oxygen and 2·34 per cent. of carbonic acid. These results confirm the observations previously made by Mr. Atkinson and the writer on atmospheres which have been rendered just extinctive by black-damp. The mean of all our observations gives 17·35 per cent. of oxygen as the proportion at which lamps and candles are extinguished in air vitiated by black-damp or choke-damp. Such air causes no danger or distress. It is perhaps well to add that the candle test is worse than useless in cases where intensely poisonous gases such as sulphuretted hydrogen or carbon monoxide may be present.

Choke-damp, similar to that met with in wells, must frequently be met with in mining operations, and it seems possible that some of the black-damp met with in coal-mines may originate from oxidation, not only in coal, but also in stone or clay above or below the coal, and particularly where ironstone or ferrous salts in any form are present. The facts mentioned by Messrs. Elwen, Hassam, Statham, and Lindop,* favour this view. The black-damp of coal-mines seems, however, to be, as a rule fairly constant in composition and to differ usually from the choke-damp met with in wells. The analyses published by Mr. Atkinson and the writer† showed that the black-damp from pits in the North Staffordshire and Shropshire districts consisted of nitrogen, containing about 12 to 15 per cent. of carbonic acid. Since the publication of the paper the writer has analysed some additional samples, collected either by Mr. Atkinson or himself, of black-damp, or return-air (which always contains black-damp) from different coal-fields in England and Scotland. The results are contained in the following table. It will be seen that, with one exception (the samples from the Bulhurst workings at Talk colliery), the composition found is very similar to that of the specimens previously analysed.

A few remarks with regard to these samples may be of interest.

Nos. 1 and 2 have some bearing on the Timsbury explosion, a question having arisen as to the possible presence of explosive gas in the cavity in

* *Trans. Fed. Inst.*, vol. viii., pages 563 and 566.

† *Trans. Fed. Inst.*, vol. viii., page 549.

TABLE II.

Localities.	Congyre (Timsbury) Colliery, Somerset. Old road at foot of Peter's Gug. 22nd February, 1895.	Same Colliery. From cavity in roof near where shot was fired which caused the explosion of 6th February, 1895.	Old Engine Dip, West Bulhurst Workings, Talk o' the Hill Colliery, North Staffordshire. 11th April, 1895.	Top of same Dip. 3rd May, 1895.	West Bulhurst Main Return. Same Colliery. 11th April, 1895.	Main East Return. Same Colliery. 11th April, 1895. *	South Side Main Return. Great Fenton Colliery, North Staffordshire. 10th April, 1895.	Hole leading to Old Workings. Burghlee Pit, Mid Lothian. 9th October, 1895.	Upcast Shaft. Same Pit. 9th October, 1895.	Upcast Shaft. Tylorstown Colliery, South Wales. 20th February, 1895.
Composition of the sample—										
Oxygen	15·55	20·87	11·93	10·14	19·77	20·10	20·31	13·75	20·50	20·27
Nitrogen	80·57	79·08	80·41	83·24	78·43	77·72	78·56	81·75	79·22	77·66
Carbonic acid	3·88	0·05	3·14 3·13*	3·41	0·43 0·47*	0·23 0·24*	0·30 0·27*	4·49 4·52*	0·27 0·29*	0·20 0·21*
Fire-damp	0·00	0·00	4·52	3·21	1·35	2·00 1·90*	0·83 0·88*	0·00	0·00	1·87
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Otherwise expressed—										
Air — Oxygen	15·55	..	11·93	10·14	19·77	20·10	20·31	13·75	20·50	20·27
Air — Nitrogen	58·83		45·13	38·37	74·79	76·04	76·84	52·02	77·56	76·69
Air — Carbonic acid	0·02		0·02	0·01	0·03	0·03	0·03	0·02	0·03	0·03
Air — total	74·40		57·08	48·52	94·59	96·17	97·18	65·79	98·09	96·99
Black-damp — Nitrogen	21·74	..	35·29	44·87	3·64	1·67	1·72	29·73	1·66	0·97
Black-damp — Carbonic acid	3·86		3·11	3·40	0·42	0·21	0·25	4·48	0·25	0·17
Black-damp — total	25·60		38·40	48·27	4·06	1·88	1·97	34·21	1·91	1·14
Fire-damp	0·00	..	4·52	3·21	1·35	1·95	0·85	0·00	0·00	1·87
	100·00	..	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Composition of the Black-damp—										
Nitrogen	84·92	..	91·90	93·35	89·66	88·83	87·31	86·90	86·91	85·97
Carbonic acid	15·08		8·10	6·65	10·34	11·17	12·69	13·10	13·09	14·03
	100·00	..	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

* Duplicate determination.

the roof of the intake road, or in the neighbouring old workings. Fire-damp and carbon monoxide were absent in the samples, which were sent by Mr. W. N. Atkinson.

No. 3 was obtained from near the roof at a fire-stopping at the bottom of a disused engine-dip. The oil-lamps, which we carried in penetrating down this dip, were extinguished without previously showing any marked cap. The lamps nearest the floor kept alight much longer than those held at the ordinary level, the specific gravity of the mixture of black-damp and fire-damp being lower than that of air. A Clowes hydrogen lamp was finally extinguished after showing a 3 per cent. cap, so that we were left with only an electric lamp. To prevent accidents we carried with us a mouse and carefully watched its symptoms, particularly as the presence of carbon monoxide from the old gob-fire was suspected. The sample contained no trace of carbon monoxide. Sample No. 4 was obtained from the roof at the top of the same dip, at a place where the hydrogen-flame was extinguished.

Sample No. 5 showed a very slight but distinct cap (estimated at 1·5 per cent.) on an oil-flame. In sample No. 6, a 2 per cent. cap was indicated by both the oil and hydrogen-flames. In sample No. 7, the hydrogen-flame gave a distinct cap (estimated at 0·5 per cent.), and the oil-flame nothing. In sample No. 10, a slight cap (estimated at 1·5 per cent.) was visible on an oil-lamp. These cap observations are perhaps worthy of record as showing that with proper precautions as little as about 1 per cent. of fire-damp may be detected under ordinary conditions with an oil-flame.

The samples for analysis in this paper and the previous one by Mr. Atkinson and the writer were collected in dry glass bottles, provided with good corks, soaked in paraffin wax. Analyses of pit gases, and particularly of return air, are, the writer believes, often more or less vitiated by collection of the samples over water or in metallic vessels liable to oxidation, or by the employment of methods of determination which allow of serious inaccuracies.

The PRESIDENT said that the members were indebted to Dr. Haldane for his paper and for others which he had contributed to the *Transactions* of the Institution: they contained the result of scientific investigations by which he had succeeded in upsetting many of their previously accepted theories.

Mr. A. L. Steavenson (Durham), in moving a vote of thanks to the writer of the paper, said that he believed this paper was the first on the subject which had been presented to The Federated Institution of Mining Engineers or to any of the federated institutes. The quantities of carbonic acid gas met with in mining nowadays was small, as the large amount of air produced by mechanical ventilation removed it almost entirely. In Cleveland, he thought that the iron-mines were more subject to carbonic acid gas than other districts: 400 and 500 cubic feet of air was supplied per minute per person employed, and of course neutralized the gas, otherwise they would find it very troublesome. Large quantities of blasting-powder were used in these mines; in some of the mines as much as ½ ton in eight hours, and they were sometimes anxious about the quantity of carbonic acid in the return-airways. He had had the gases thoroughly tested, but found nothing of a sufficiently dangerous character to necessitate further notice.

In his early days, it was a very common thing, in the absence of mechanical ventilators, to burn candles, held on one side because they would not burn when held upright; but, as their President had told them in his address, that state of things was of the past.

The Northallerton wells were situated on the outcrop of the New Red Sandstone, and when boring for salt in South Durham hydrogen had frequently been found. He thought it was quite possible that if the gas from the Northallerton wells were tested, it might be found to be hydrogen from the New Red measures.

He had used petroleum engines in the Cleveland mines for some time, and these, if not carefully watched, would give off carbon monoxide.

The great point which struck him in perusing Dr. Haldane's paper was the small proportion of carbonic acid necessary to constitute a dangerous risk; he thought it needed a good deal less than mining engineers had generally considered to be dangerous. In 1863 or 1864, the Royal Commission on the condition of mines other than coal-mines made extensive researches, he gave evidence as to their condition, which even at that time was not bad, although they were not so well ventilated as now. He thought that Dr. Haldane would find that the *Report* of this Commission contained useful information on the subject of the occurrence of carbonic acid in mines, and he would also find some carefully-made experiments as to the quantity of carbonic acid in which a man could live.

Mr. J. B. Simpson (Newcastle-upon-Tyne), in seconding the vote of thanks, asked Dr. Haldane whether he could give an account of the strata

passed through in the different wells of which his paper treated. It might be important to know whether there was sand or gravel in any portion of the well, or whether it was all solid rock. The nature of the strata might have something to do with the occurrence of the gases; a stratum of clay might retain gases which would issue freely from other strata. A point on which he would have expected Dr. Haldane to have arrived at a conclusion was as to whether gases were met with in all well-sinking, or only in certain places.

Mr. H. G. GRAVES (London) asked whether Dr. Haldane knew anything of the virtues of alcohol in reference to gaseous poisoning. Mr. Thomas Hooson, writing in 1747, gave an account of a sinking where the men at work were entirely overcome by damp. One or two workmen went down to their rescue, but they in turn were overcome. But the old writer, in his quaint way, went on to say that a tinker coming by, badly overcome with drink, volunteered to go down; he did so, and successfully brought up all the men, and was none the worse, except that he was violently sick.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, Newcastle-under-Lyme) said that Dr. Haldane's investigations on the choke-damp of wells seemed to have confirmed that gentleman's previous opinion that choke-damp resulted from the oxygen of air being partly absorbed and partly combined with carbon to form carbonic acid gas. His observations seemed to favour that view, inasmuch as at certain periods air was drawn in, and at certain other periods gases were evolved; but he (Mr. Atkinson) thought it would be very desirable if some means could be taken to ascertain whether choke-damp did not in some cases pre-exist in the strata. It seemed difficult to believe that in workings in coal-mines—fresh workings —where in some cases choke-damp was given off very rapidly, and more or less constantly, that the black-damp should be the result of changes in atmospheric air. He (Mr. Atkinson) had tried to devise some method by which it could be ascertained whether in some cases the choke-damp did not exist already formed in the same way as fire-damp existed, but so far, he was sorry to say, he had not succeeded in arriving at any satisfactory method.

Mr. JEREMIAH HEAD (London) said it seemed to him the great feature of Dr. Haldane's paper was that choke-damp, as found in wells, consisted much more of free nitrogen and less of carbonic acid than had hitherto been supposed. If that were so, or in any case, it seemed to suggest that there was something like a breathing action in wells. With

the barometer high, the atmosphere passed into the well and into the surrounding strata; with the barometer low, it came back again, but in somewhat different form: poorer in oxygen, richer in nitrogen, and richer in carbonic acid. If that were so, it was an operation similar to that which occurred in combustion, whether the combustion of a furnace or the combustion of breathing in the human body. In those cases the combination of oxygen with oxidizable substances always produced heat, therefore one might suppose that the oxygen as it passed into the strata became chemically combined with some oxidizable substance, and the returning air would be hotter than when it entered. He would like to ask Dr. Haldane whether he had tested the temperatures of the air when entering the well, as compared with the air or the gas when coming out of the same well. Mr. W. N. Atkinson had spoken of the oxygen as disappearing, but scarcely suggested whether it disappeared in the way of chemically combining with something in the strata, or whether it was separated without that chemical combination. In the latter case, if there were any means of separating oxygen from the atmospheric air—from the nitrogen—without its combination in the way of combustion, they might get some very valuable hints for the production of oxygen for use in combustion afterwards. This was a problem which he believed had not been attempted in the past; that is to say, the separation by mechanical means, or by means other than chemical, of oxygen from nitrogen, for the purpose of getting air for purposes of combustion richer in oxygen than the ordinary atmospheric air was. Therefore, if it could be shown that the oxygen disappeared from the air entering the wells, without being combined with anything which would suggest that the air was not hotter than when entering, they might get some valuable hints in that way. But if experiments showed that the temperature of the outgoing air was higher, and higher to the extent corresponding to the loss of oxygen, then they might be pretty sure that there was combustion somewhere in that stratum, which might be a valuable guide to further research.

Dr. J. S. HALDANE, replying to the discussion, said that the composition of the gases taken from the wells at Northallerton had been ascertained by Mr. Fairley, who made the observations in the wells, and he found that pure air came out; but he was told that when the wells were first sunk choke-damp had been found, probably the same sort of gas as that found at Redwick and the other places.

The percentage of the moisture present made a great difference in the effects of the air met with in badly ventilated places. If the air was

warm, and at the same time moist, the men could not get rid of the heat formed by their bodies, and could not work efficiently under those conditions. If the mine was hot, the air must be dry, or fairly dry, for the miners to work with any sort of comfort. Bad effects were often due to the moisture or high temperature rather than to contamination of the air with carbonic acid or other gases. The ordinary return-air in many mines contained as much as 0·40 per cent. of carbonic acid gas, and less than 20 per cent. of oxygen, and according to the data found in text books, including Dr. Angus Smith's, they would imagine that air was dangerous, or at any rate not good for the health of the workmen. In such air, however, one felt quite well, and there was no reason to suppose that it did the least harm to anyone. With regard to Mr. Simpson's remark as to the nature of the strata in the well, he intended to have given the data asked for, and he would incorporate it in a note.*

As regards the possible presence of choke-damp in all wells, from what he had seen he was sure that in many borings there was no choke-damp ever met with; he did not know in the least which wells or borings might be liable to sudden eruption of choke-damp. It would, he thought, be practically easy to find out. If there was reason to suspect danger or trouble from this cause, the boring should be watched on a day when the barometer was falling rapidly or was low, and if there were any choke-damp it would appear on the day of a low barometer.

It was possible that the tinker referred to by Mr. Graves had gone down at a time when the air was better than when the others went down. It was difficult to tell what might happen; perhaps one or two men might be killed, and the last man down effect a rescue. Moreover, different people seemed to be sensitive in a different degree to the effects of want of oxygen. In putting persons in a closed chamber at the laboratory at Oxford, it had been found that one or two were distinctly more sensitive to the want of oxygen than others.

The pre-existence of gas in the strata was a question which Mr. W. N. Atkinson and himself had discussed a good deal together, and it was a difficult one on which to come to a positive conclusion, as yet, one way or the other. So far, they had not themselves met with any cases in which the formation of choke-damp could not be explained from the penetration of air into the strata. He had tested the gas given off by coal; he had put coal over mercury, and if it were a fiery coal it would continue to give off fire-damp slowly for a year or more. At first the resulting gases

* *Trans. Fed. Inst.*, vol. xi., page 270.

contained 10 to 15 per cent. of nitrogen, afterwards nothing but pure fire-damp was given off, which looked as if the nitrogen was not evolved from the coal.

He had made no observations as to the temperature of the air issuing from the wells, and he thought that it would be very difficult to do so, as the air came out so slowly, and became mixed with large volumes of air which were cooled in the well. He had often thought of the question raised by Mr. Head as to the heat produced by oxidation, and he believed that the disappearance of oxygen in coal-mines was due to the fact that part of the oxygen combined with hydrogen to form aqueous vapour, and part with carbon into carbonic acid. He thought that a large amount of heat was formed by this oxidation. Of course the return-air was hotter, but it was difficult to say how much of the increased heat was due to oxidation: calculating from the volume of black-damp formed and the carbon and hydrogen oxidized, the heat so caused would be enough, he believed, to heat the air-current 100 degs. Fahr. The greater part of that heat was, as a matter of fact, absorbed by the strata, but he thought that probably oxidation had a great deal to do with the temperature in mines—at all events it certainly had something to do with it.

Mr. JOHN MCLAREN read the following paper on "Road Locomotives":—

ROAD LOCOMOTIVES.

By JOHN McLAREN, M. Inst. C.E., Leeds.

No sooner had George Stephenson demonstrated the feasibility of hauling heavy trains on railroads than the idea "took on," and in a very few years the country was covered with a network of lines, the development of which is one of the greatest marvels of this century.

The use of steam-engines for hauling passengers and goods on common roads engaged the attention of engineers long before the days of Stephenson's triumphs, and the slow growth of this means of transport is almost as great a wonder as the marvellous development of the railway system.

The subject is one which bristles with difficulties, partly of a mechanical and partly of an administrative character. Competent mechanical minds have practically overcome the first of these obstacles, and the development of the use of steam-engines on common roads is now awaiting the removal of the restrictions imposed upon it by objectionable legislative enactments. Difficult as it has been to produce a workable road-locomotive, it appears to be more difficult to obtain reasonable facilities to use it.

Prejudice, *laissez faire*, and an unreasonable fear on the part of the authorities that the use of road-engines would be dangerous to the public and injurious to the roads themselves, account in some measure for many of the obstacles placed in the way of those who would avail themselves of this mode of transport. At the same time, it is hardly creditable to us as a nation that greater restrictions should be imposed upon the use of traction-engines in Great Britain than in any other country of the world. In spite of the discouragements of the legislature, it is estimated that some 8,000 traction engines are at work in this country. This fact alone affords ample evidence of the need of such engines, and is at the same time a justification of those who are agitating for greater freedom in using them.

At present they are used principally for agricultural purposes, such as threshing, steam-ploughing, and other work for which it is necessary that the tackle and motive power should be rapidly moved from place to place.

In addition to this, however, a considerable number are used for the haulage of stone, coal, lime, bricks, and other material, which, for one reason or another, it may not be convenient to send by rail.

The conditions under which traction-engines are required to work are so various, the roads upon which they travel are so uneven, both as to formation and gradient, that details of construction have to be somewhat varied to suit varying requirements; but, on the whole, the most efficient road-engines are those which most nearly approach in design and appearance to what may be called the locomotive pattern.

Most of the engines now at work have single cylinders only, but where fuel is dear and water scarce it is a decided benefit to employ compound cylinders, although each type has its special advantages. A single-cylinder engine is able to lift itself or its load out of a soft place or over a bad length of road better than a compound engine, but the latter will give off the same power, in a steadier manner, with a consumption of from 25 to 30 per cent. less fuel and water than the single-cylinder engine. It has also the advantage of working with less noise, because, as the steam is expanded down to nearly atmospheric pressure, the noise of the exhaust is much reduced, and the consequent danger of frightening horses diminished.

The drawing (Figs. 1 and 2, Plate XVI.) shows the multitubular boiler usually employed. This has the double advantage of being an excellent steam generator, and forming a frame or support upon which the engine may be built. The cylinders and other working parts are bolted direct to the boiler, which is constructed with a sufficient margin of strength to withstand the racking strains of the reciprocations of the piston. The power of the engine is transmitted from the crank-shaft to the main axle by means of a train of steel spur-gearing, which not only enables a comparatively small engine to exert a great tractive force, but admits of the use of large driving-wheels and reduces the rate of speed to that prescribed by law.

The plates forming the outer shell of the fire-box are usually carried upwards and backwards in the shape of hornplates, and make a light, yet strong provision, upon which the brackets for the crank-shaft, intermediate shafts, and main axle may be bolted. These various shafts are thus kept in line, and as none of the bolts by which these bearings are fixed enter the steam or water spaces of the boiler, the risk of leakage is practically obviated.

The pressure of steam used varies from 100 to 200 lbs. on the square inch, so it is evident that boilers and working parts must be of the best construction throughout, and it is bare justice to say that the quality of material and workmanship employed by the leading traction-engine makers are equal in every respect to those of the best locomotive practice.

The cranks, intermediate shafts, and main axles, are generally of best forged mild steel running in gun-metal or phosphor-bronze bearings. The spur-gearing is arranged so as to give a choice of speeds upon the road, viz., 2 miles per hour in the slow and 4 miles per hour in the fast speed, the latter being the maximum rate at which these engines are permitted by Act of Parliament to travel. In order that the engine may be able to turn sharp corners without the inner wheel surging or slipping, a differential or compensating motion is employed. This is generally fitted inside a winding-drum, which forms at once the casing of the differential gear, and a means by which the power of the engine may be concentrated upon a steel rope coiling upon its periphery, to be used for a variety of useful purposes, such as hauling the engine, or its load out of a soft place, or up a steep hill.

The steerage is effected from the footplate by means of a worm and wheel at one end of a horizontal shaft crossing in front of the fire-box. Two chains are coiled on this shaft, one over the top and the other under the bottom, so that when one is winding on the other is unwinding. These two chains are fixed to opposite ends of the front axle, which is free to turn in a horizontal direction upon a central stud or pin—so that the act of winding or unwinding the chains on the horizontal shaft turns the front wheels, and guides the engine into any position which may be required. Provision is also made whereby the front axle may rock vertically, so that the wheels may accommodate themselves to any inequalities of the road.

Suitable accommodation for coal and water are provided in the tender. The water capacity may be increased, if necessary, by the addition of an extra tank under the barrel of the boiler. The engine must be fitted with link-motion reversing gear, and the fly-wheel should be so arranged that it may be used when required for driving any kind of machinery by means of a belt.

One of the most important features of a traction-engine is the design and mode of construction of the road-travelling wheels, and in this connexion we have an illustration of the absurdity of legislative restraint. The whole efficiency of the engine, either for useful work or for destructive effect upon the roads, centres in the main driving-wheels. If these

can be made to take a good grip of the road, so as not to skid or slip, the damage done by the passage of a traction-engine over it will be inappreciable. On the other hand, the wheels may be so made as to tear up the road and do the greatest possible damage in the least possible time. The law requires the road wheels to be made in one of two ways —either "cylindrical and smooth soled," or shod with diagonal cross-bars, not less than 3 inches wide, not more than $\frac{3}{4}$ inch thick, and not exceeding 3 inches apart. The first of these designs is calculated to do the least damage to the road, but in consequence of the poor adhesion obtainable by this form of wheel, it is seldom or never used, and traction-engine makers are thus compelled by law to use the cog-wheel pattern of road wheel, formed by riveting steel cross-bars across the face of the cylindrical wheel, and when from any cause whatever this wheel begins to slip, it at once begins to destroy the piece of road upon which it happens to be surging, just as the teeth of a circular saw cut into a log of timber which may be pressed against it. In spite of any desire on the part of engineers to make a better wheel, and of engine-owners to use such a wheel when made, local authorities cannot sanction their use without flying in the face of the Act of Parliament. Improved wheels can be and have been made, and while we have one large county welcoming their use, in spite of the Act of Parliament, we see the adjoining county refusing to allow them to work under any circumstances, because they do not comply with the requirements of the Act of Parliament.

Figs. 3 and 4 (Plate XVI.) show the method of constructing the ordinary "cog wheel." It is formed of two T-iron rings, welded and blocked to a true circle. These are placed side by side, either with a wrought-iron cover-plate and steel cross-plates riveted on, as at *H*, or with the cross-plates riveted directly to the T-rings, as at *I*. In either case the boss is of cast-iron, with T-headed wrought-iron spokes cast into the boss at one end and riveted to the T-iron rings at the other.

The improved wheel, to which reference has already been made, has been brought out by Messrs. J. & H. McLaren and Mr. I. W. Boulton. As the weight which can be hauled by the engine depends on the adhesion of the driving-wheel to the ground, the special feature of this wheel (Figs. 5 and 6, Plate XVI.) is the arrangement whereby the surface of the rim of the wheel bearing upon the ground is increased by the pressure upon it of the weight of the engine. It has a broad cast-iron rim, *a*, with cells or slots, *b*, about 6 inches square, cast all round its circumference. These cells are 6 or 8 inches deep, closed at the bottom, but opened towards the outside of the periphery of the wheel. A hard wood

block, *c*, cut lengthwise of the grain, is fitted loosely into each cell, one end projecting a little beyond the rim of the wheel, and the other bearing upon an elastic pad or buffer, *d*, between it and the bottom of the cell. A suitable provision is made to prevent the blocks from dropping out as the wheels revolve. When the engine is in motion the weight upon the rim of the wheel compresses the blocks so that those in the lowest and adjoining cells come in contact with the road at the same time, forming a large and continuous flat tread to the wheel, and so increasing its adhesion on the road. On paved streets the use of these wheels is specially advantageous, for not only is the tractive power of the engine enormously increased, but possible damage to the paving setts, caused by the chipping action of ordinary wheels, is entirely avoided. A considerable number of engines furnished with these wheels have been at work in the Manchester district for some years, and the results have been so satisfactory that certain local authorities, who, by virtue of special powers had practically prohibited the use of traction-engines within their districts, have waived their restrictions in favour of engines mounted upon these wheels. As an instance of the advantage resulting from the use of these wheels, it may be stated that recently, an 8 horse-power engine fitted with them moved a boiler weighing 30 tons, on a trolly of 9 tons weight, from Dukinfield to Oldham without any difficulty.

For many years the mounting of these engines upon springs formed an almost insuperable difficulty. This has now been overcome, and the firm with which the writer is connected now mount most of their engines upon strong laminated springs similar to those used on railway-locomotives.

The advantages are obvious. The main source of wear and tear in the engine is occasioned by the shocks to which it is subjected in passing over rough and uneven roads. Pavements are especially trying and destructive. The wood-block wheels already described obviate to a considerable extent the necessity for springs, as they effectually break the shocks and take off the worst of the jar due to the passage of the engine over hard roads. But for lighter engines the arrangement of springs illustrated in Figs. 7, 8, and 9 (Plate XVI.) has been found to work most successfully. The springs *J* rest in a shoe *J'*, formed of a steel casting .suspended underneath the engine. Each spring takes a bearing upon the axle-boxes *L L*, which are free to slide up and down in the horn-blocks or guides *M M*. These guides are fixed to the side-plates *N N* of the fire-box, which are carried backwards for the purpose as already described. The connexion between the spring and the axle-

boxes is through the suspension links K' K', which are carried by the cross-head K. Sufficient movement is allowed to the action of the springs to take off all undue shocks from the engine, but the range is so limited that it has been found possible to dispense with the complicated mechanism for keeping the main driving-wheel and pinion in exact pitch, and in practice it is sufficient to make the teeth of these wheels somewhat longer, so as to admit of a slight in-and-out movement, corresponding with the travel or range of the axle-box permitted by the action of the springs.

Having now glanced at the principal features of the construction of traction-engines, the next point to consider is what practical purposes they can be made to serve. Their use in agriculture is both general and well known, but their employment in industry is not so universal as their handiness and usefulness warrant. Nevertheless, it is extending, and as legal obstacles disappear, and as the advantages derivable from their use are better understood, their employment will become more general. In districts where there are no railways, and where from the scarcity of traffic it would not even pay to build light railways, the use of traction-engines has been found most advantageous. In the Peak district of Derbyshire, on the borders of Wales, and in many other outlying districts, the traction-engine has been welcomed, not only as a means of bringing up supplies of coal and other necessaries, but for carting down the produce of the district to the railway stations. It has thus been a means of opening up many local industries, such as quarries or mines which could not otherwise have been worked at a profit in consequence of the cost of transporting their produce to the nearest markets. In this way work has been found for many of the inhabitants who would otherwise have had to go further afield to seek employment. Thus a compensation is provided even in the event of the engine doing some slight damage to the roads, as the rateable value of the district is increased, and all the workers and tradespeople in the neighbourhood are either directly or indirectly benefited.

Even in districts where railways abound: indeed, it may be said that specially in such districts, traction-engines are largely used. In the Leeds and Wakefield districts of the West Riding their use has now become general. In one village alone, about eight traction-engines are regularly working, mostly hauling stone from the quarries to the saw-mills, and thence to the railway-stations. In the same district, they are largely used for hauling bricks from the makers' yards to the numerous

buildings in course of erection in the neighbourhood. For this purpose they possess many advantages over even transport by rail, because for comparatively short journeys the railway rates are not only relatively high, but in most cases the material has to be carted to the station in the first instance and there loaded into railway-waggons, and then on its arrival at the other end of the railway journey it must again be transferred into carts and conveyed by horses to its final destination. This is not only a costly proceeding but involves considerable damage by breakage to the material itself, which in the case of bricks, for instance, or tender coal is an important consideration.

In estimating the cost of transport by traction-engines due weight must be given to these important factors. In the following calculations they are left entirely out of account, so that in order to arrive at a fair comparison credit must be given to the traction-engine in a proportion which will vary in every individual case.

The net useful load which can be drawn by a traction engine depends altogether upon the nature and condition of the road. With ordinary wheels, on smooth pavement or on slippery or greasy roads, the engine may have enough to do to propel itself on an incline, up which in other circumstances it might be able to haul a considerable load. The following table shows approximately the gross and net efficiency which can be obtained from these engines working on macadamized roads in fair condition. The figures apply to single-cylinder engines cutting off the steam at about three-quarters stroke :—

Nominal Horse-power	6	8	12
Weight of engine (empty), tons	8	9½	13
Weight of engine in working order, tons ...	9	11	15
Steam pressure per square inch, pounds	130	130	130
Actual horse-power at 400 feet of piston speed per minute	25	35	55
Number of waggons in train	2	2	3
Weight of empty waggons, tons	5½	5½	8¼
Net useful load suitable for level roads, tons ...	12	16	21
Gross load (engine, waggons, and contents) on level, tons	27½	33½	44¼
Net useful load on incline of 1 in 10, tons ...	9	12	18
Net load on incline of 1 in 10 (extra good roads), tons	10	14	21

Cost of Working.—With respect to the cost of working traction-engines on common roads the following figures based upon actual experience may be taken as a fair average when working under normal condi-

tions. They refer to an 8 horse-power single-cylinder road-locomotive or heavy haulage engine. It is used for hauling bricks, etc., to an average distance of 17 miles.

The cost of the engine ready for the road was £560, and the price of four waggons mounted on springs, and fitted with screw-brakes, draw-bars, etc., complete was £332, or a total capital expenditure of £892, say £900.

	£	s.	d.
Interest on £900 for 12 months at 5 per cent. per annum ...	45	0	0
Depreciation and renewal of capital at 15 per cent. per annum	135	0	0
One driver, 52 weeks at 30s. per week £78 0 0			
One steersman ,, 20s. ,, ... 52 0 0			
One assistant ,, 18s. ,, ... 46 16 0			
	176	16	0
Oil, waste, stores, etc., 300 days at 2s. 6d.	37	10	0
Coal, 300 working days at 10 cwts. per day, 150 tons at 15s. ...	112	10	0
Making the total working expenses per annum	£506	16	0

Taking a useful load of only 12 tons each trip, the total weight handled in 300 working days would amount to 3,600 tons carried a distance of 17 miles, or equal to 61,200 tons hauled 1 mile. This divided into £506 16s. would give a rate of 1·98d., or a trifle under 2d. per ton per mile, or a saving of at least 75 per cent. compared with the cost of doing the same work by horses. This economy would be still further increased if the engine could be provided with a load both ways.

As a typical instance of what may be done with traction-engines when intelligently worked, reference may be made to the experience of a granite quarry company, near Leicester, where two 8 horse-power traction-engines have been regularly worked for several years. The quarry is situated about 3 miles from the railway-siding, and each of the engines makes about five trips per day, hauling an average load of about 13 tons per trip in two waggons. By this means about 40,000 tons per year are hauled out by the two engines, in addition to a quantity of coal and other inward traffic brought home from the station. Except that the gradients, which are not very steep in any case, are generally in favour of the load, this may be taken as a fair average result, only it must be borne in mind that some trouble is taken to see that the engines are never stopped either from snow or other obstacles. In winter, when there is snow on the ground, it is immediately cleared off by a large squad of quarry employés, as in the event of the road becoming blocked the quarry would be laid idle, and all the workers temporarily thrown out of employment. When the engines were put on to this road at first,

they cut through the soft country roads in several places. These places were filled up with waste from the quarry and covered with a thick coating of granite, and, though the original cost was rather heavy, the work was done thoroughly, and the advantage of this is now being felt in the reduced cost of maintenance.

With regard to road damage, it may be said that experience will enable an engine-owner to work his engine in such a manner as to do little or no real harm. Unfortunately, the voice of experience has not always been heeded, and the consequences have been unpleasant for the owners who have neglected its warnings, and deterrent to others who would have employed traction-engines but for the unfortunate experience of those who have only themselves to blame for their misfortunes. There are roads on which it would be absurd to try to work traction-engines, such as those formed with a thin crust of macadam over a peaty subsoil. In olden times many roads were so constructed in moorland districts, where, although they had no foundations, they were sufficient for the slight traffic and light loads of the locality. Such roads are now, however, few and far between, and no time should be lost by the local authorities in putting them into such a condition as will meet modern requirements. But so long as they exist traction-engine owners should keep off them or they may have the task imposed upon them of making a bad road into a good one at their own expense, and for the benefit of the ratepayers in the neighbourhood. Again, when the roads are sodden with rain, the systematic working of traction-engines upon them should be avoided as far as possible, as the engine and especially the waggon-wheels are liable to cut through the macadam and sink deep into the yielding subsoil. But the worst possible time to work a traction-engine upon any road is when it is soft and sticky after a long frost. In that case the wheels lift the road bodily and will ruin the best-made thoroughfare. In such a case any traction-engine owner who insists upon travelling his engine should be indicted for wilful damage and punished severely. Otherwise, the working of traction-engines on common roads is an advantage rather than otherwise, and it is a curious fact that where the greatest number of engines are at work the claims for damage to roads are fewest. This is no doubt due to the care which the owners take to keep their engines off the roads when they are not in a fit state to travel upon.

Reference has been made to the tiresome legal restrictions imposed by the legislature upon the use of traction-engines. It should be borne

in mind that no change has been made in the laws regulating the use of steam-engines on common roads for nearly twenty years, and during that time many improvements have been made in the construction of road-engines, rendering them much lighter, handier, safer, and generally much less objectionable than they formerly were, so that restrictions which might have had some justification several years ago are now not only obsolete and unnecessary but utterly absurd and merely vexatious. Not only so, but the creation of so many new local administrative bodies having some jurisdiction over highways, such as county councils and county boroughs, which have come into existence since the law was last considered by Parliament, has set up a multiplicity of authorities, with varying ideas, interests, or prejudices, most of which have been exercised to the disadvantage of the traction-engine owner.

Amongst the legal restrictions may be mentioned, first, that such engines have been held to be a nuisance at common law. Secondly, that in nearly every case the owner is obliged to obtain a license from a county council, to enable an engine to travel on any highway; and that he may have to wait nearly three months before such license can be granted; that this license, though it is evidence that the engine is constructed in accordance with the requirements of the Act of Parliament, affords the owner no protection whatever against any person or public body raising the most frivolous objections to the passage of the engine. Thirdly, that in country districts, though there may be no other traffic on the road three men are required to accompany every engine, the speed of which is limited to 4 miles per hour, one of the attendants being required to walk in front, at a distance of not less than 20 yards. Fourthly, that the road authorities have an almost arbitrary power to forbid the use of certain bridges by such engines, though the bridges themselves may be of ample strength to carry the weight without danger; and further, that although damage done to a bridge by the passage of heavy castings, or other weights drawn by horses, is made good at the public expense, such damage must be made good by the engine-owner, in case the same load should happen to have been drawn by a traction-engine. Fifthly, that certain urban authorities have been allowed to embody in their Local Acts clauses by which they are able to prohibit the use of traction-engines on any street or road within their jurisdiction.

These, and other hindrances, added to the mechanical difficulties connected with working steam-engines on common roads, account in a large measure for the comparatively slow progress in this country of this method of traction.

The time has now come for these antiquated and mostly useless provisions to be entirely repealed, and a new law passed embodying the results of past experience, strict enough to grant ample protection to the public and those bodies representing them who have to look after the maintenance of the roads, but allowing sufficient freedom to the users of traction-engines, relieving them of all restrictions which are merely vexatious and irksome, and substituting others which may be of real use. For instance, three men to work a traction-engine are quite unnecessary. In former times when engines were steered from the front it was necessary to have one man on the front platform to steer, and another behind to drive, but now when all the movements are worked from the rear foot-plate the second man on the engine is quite superfluous. Indeed, he is so much in the way that when working off the highway or in a strait place the driver invariably takes hold of the steerage-handle himself and both steers and drives. Many accidents are caused by misunderstandings between driver and steersman. This man could therefore be well spared, although when the law was made in the first instance his presence on the engine was necessary. Two men in attendance are all that are necessary, one to drive, and the other to make himself useful on foot. The requirement of a man in front might be modified, for although he must be not less than 20 yards in front there is nothing to prevent him being 400 yards, or even a mile in advance of the engine, in which case, of course, he would be of no use for assisting horses past the engine, though he might be able to give effective notice of its approach. But the attention of the man on foot might as advantageously be directed to traffic coming up from behind as to traffic meeting the engine. He might therefore have a general commission, and be left to choose his position wherever his assistance is most required.

Then, again, all drivers of traction-engines on public roads should be required to obtain a license or badge, which should be granted to all who can produce a certificate of respectability and steadiness, and who would pay a small registration-fee. This would serve a twofold purpose, for, though it would not serve as a diploma of competency, it would exclude some grossly ignorant and careless men, who, though not numerous, could be dispensed with altogether; and it would afford a means of inflicting a restraint and punishment upon drivers whose conduct was not satisfactory. The danger of having their licenses suspended or withdrawn in case of misconduct would have a salutary effect upon them.

All owners of traction-engines should be compelled to insure their boilers with some recognized boiler-insurance company. This is necessary

in the interests of the owners themselves, as well as the public, as at present many boilers are being worked in a very unsafe condition; and the proposed insurance would ensure periodical inspection and the carrying out of all necessary repairs before the state of the boilers became dangerous.

The limitation of the county license to the county in which it is granted imposes great hardships upon engine-owners whose headquarters are near the boundary of two or more counties, for while one man in the centre of a district may be able to cover a large area with one license, another man may require three or four licenses from different county authorities in order that he may be able to cover the same amount of ground. Again, a man hauling a boiler or a large casting may have to pass through several counties, and might for one solitary journey require six or eight licenses, or run the risk of being brought before the magistrates and fined in every separate district he passes through. When a license is once granted it should enable the owner to take his engine wherever he chooses, just as a man can do with his carriage or his gun for which he has taken out a license.

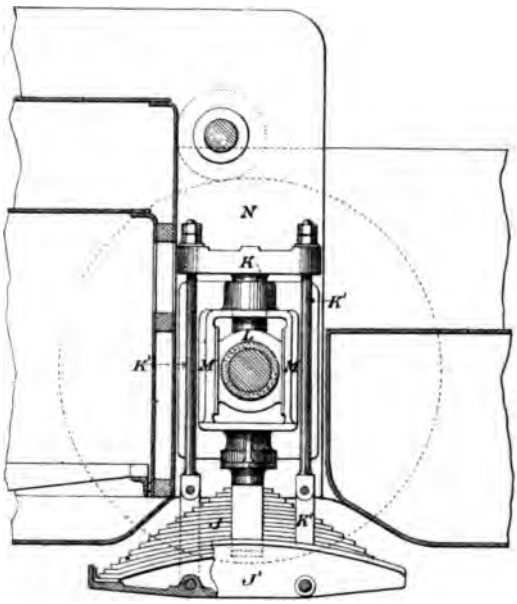
The time has now come when the nuisance clause should be absolutely repealed, and the granting of a license to a traction-engine owner should give him a certain *locus standi*, and afford him a certain amount of protection—so long as he carries on his business in an unobjectionable manner. At present the law exacts as much as possible from him, and gives him practically nothing in return.

A liberal limit of weight should be fixed for all engines, and all bridges should be thrown open to them. Those which are not strong enough to carry a 15 tons engine are too weak for modern traffic requirements, and should be strengthened up at the public expense. It is absurd to say that a weight of 20 tons may be hauled over a bridge by horses and any damage caused to the structure by its passage shall be made good by the authorities, while the damage done by a weight of 15 tons hauled by a traction-engine should be made good by the owner of the engine.

The power to make regulations for the working of traction-engines should be taken away from the local authorities, who cannot take more than a parochial view of the subject, and should be put into the hands of some central authority which could take a broader view of the question, and would make bye-laws for the advantage of the country at large.

Traction-engine owners have been much harassed by the views taken by certain of our law-courts n interpreting the meaning of "extraordinary

FIG. 7.



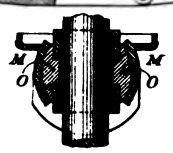
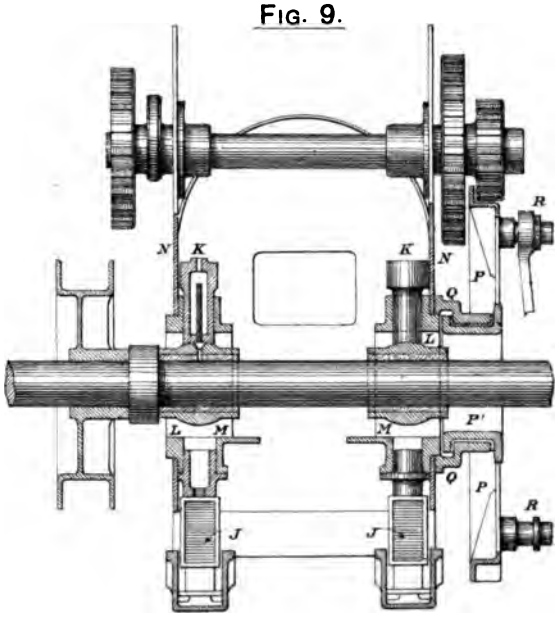


FIG. 8.

Scale, 1 Foot to ½ Inch.

FIG. 9.



Scale, 1 Foot to ½ Inch.

traffic." Some have held that the traffic if hauled by horses might be considered "ordinary," but if hauled by means of traction-engines it became "extraordinary." This clause has given rise to much expensive litigation, without any clear definition being arrived at. This matter requires consideration and settlement on a broad and liberal basis, so that engine-owners may know where they stand and what their responsibilities are without the necessity of going to heavy legal expenses to find out.

The limit of speed might also be raised with great advantage to the owners and users of traction-engines, and without prejudice to the public. There is no reason in the world why the limit of speed in towns should not be raised to 4 miles, and in the country to from 6 to 8 miles per hour. The fact that so many engines are at work in all parts of the country, with practical immunity from accident, is evidence that the time has come when these irksome restrictions may be entirely removed, and when this is done there will no doubt be a considerable development of the use of steam-engines on common roads, to the great advantage of the community at large.

Mr. JEREMIAH HEAD (London), in proposing a vote of thanks to the writer of the paper, which was a very excellent and interesting one, said that he (Mr. Head) happened to take a special interest in the subject because, in the year 1859, he was associated with the late Mr. John Fowler, the inventor of the steam-plough, and in that capacity had very considerable experience of road locomotives, one of the principal uses of which was then (and had been ever since) for steam-ploughing purposes. The steam-plough, as invented and perfected by Mr. John Fowler, was first organized and developed by Messrs. Ransome & Sims, Ipswich; afterwards by Messrs. Stephenson, of Newcastle-upon-Tyne, where he (Mr. Head) was a pupil just out of his time and entrusted with the development of that work. About a year later, he went to Leeds, when the perfecting of the steam-plough was taken up by Messrs. John Fowler & Co. The wheel shown in Figs. 3 and 4 (Plate XVI.), was designed at that time, except that the ends of the blocks where they joined the rim were now laid out; showing it had been found that one or two rivets were not sufficient to prevent its getting loose. The boiler, as illustrated in Fig. 1 (Plate XVI.), was very much the same. It was then found that steam-ploughs could not be successfully worked, so long as

they had to be drawn by horses; they were then made automotive. Mr. McLaren had had a great deal of experience with road locomotives since that time and he had brought before the meeting certain improvements which he had made. Mr. McLaren recommended the wheel shown in Figs. 5 and 6 (Plate XVI.), and complained that it was not properly appreciated by public road authorities, etc. He understood Mr. McLaren to say that the wooden blocks pressed against an elastic substance marked *d* in the drawing. He thought that it had not been stated what that substance was; probably it was india-rubber, but he supposed the object of the invention was that the pressure on the roads should be limited to the elasticity of the india-rubber, also, obviously, that as the wheel got worn out the travelling surface could be renewed at comparatively cheap expense, and partially renewed instead of entirely. At the time he had referred to, the wheels were smooth, as shown in Figs. 3 and 4 (Plate XVI.), except that they had the diagonal plates described by Mr. McLaren, which were then put on for the first time. For travelling over fields, knife-shaped projections called spuds were temporarily used, and enabled the engine to go along on soft land. In Figs. 7, 8, and 9 (Plate XVI.) Mr. McLaren showed an adaptation of springs and of ball-and-socket joints to the bearings of the aftermost axle—that was of course a great improvement. Mr. McLaren said that was adopted about four or five years ago, but he (Mr. Head) thought it was very much older, as he distinctly remembered—at the time he had spoken of—that they recognized the necessity of making the axle so that one wheel could rise in a slot without the other necessarily rising at the same time, but they used no springs.

No doubt, traction-engines were a great necessity, and the legal impediments to their use were very serious; and the Government, instead of promoting trade and commerce, in this case, as in many others, had done their best to impede progress, and had so given a very distinct advantage to their foreign competitors in that respect. He did not mean to say that the Government in this respect did not represent truly the feeling of the country, for Englishmen as a whole were too conservative; if we did not understand things we opposed any alteration of the laws until we did understand them, that is to say, a restriction which was considered necessary generations ago was allowed to remain, preventing expansion of trade and commerce, until the average voter understood their necessity.

One idea occurred to him with regard to Mr. McLaren's paper, and that was how far the new autocar system—where the actuating power

was mainly either electricity or petroleum—might supersede the necessity for heavy locomotive engines. There were, of course, great advantages in the use of petroleum for such purposes, as it avoided the necessity for water in producing power, and merely required fuel. In the case of the steam-engine, the water to be carried was ten times the weight of the fuel necessary for the engine; petroleum had one and a half times the actual heating energy of coal, hence it was easily seen that something like sixteen times the material (water and fuel together) must be carried in the case of the steam-engine than was necessary with the petroleum-engine for the same amount of work. Engineers could not help being impressed with the fact that road locomotion was on the eve of a revolution, and the time was coming when autocars, driven by petroleum and avoiding the use of water, might become of general utility. On the other hand, road locomotives were largely employed to drag heavy loads, and as a considerable amount of weight was necessary to get the requisite adhesion of the wheels, that was, of course, in favour of the use of steam-propelled road locomotives.

Mr. A. L. STEAVENSON (Durham), in seconding the vote of thanks, asked Mr. McLaren why he continued to use the old nominal horse-power? It seemed rather a pity to perpetuate the rating of an engine at 12 when it was really 55 horse-power. Mr. McLaren considered that the restrictions which legislative enactments had placed upon road engines should be removed. He did not altogether agree with him in that opinion. He (Mr. Steavenson) happened to drive a horse which, as a rule, was quiet, but if ever they met a road-engine, he had to get out and lead the horse past; if the number of road-engines were increased he would be reduced to the necessity of riding a bicycle or getting a road-engine to carry him about. The chief value of the road-engine seemed to be in carrying considerable quantities of material in out-of-the-way places; if the cost of steam haulage along an ordinary road did not exceed 2d. per ton per mile this was a useful fact to bear in mind where minerals were worked far from the railway or place of shipment.

Gradients were not referred to in the paper; it would be useful to know what gradient was applicable to this class of engine.

Mr. HOLROYD SMITH (London) congratulated Mr. McLaren on his paper, and on his improvements in road locomotives. He happened to have in his possession a photograph of the early work produced by Mr. McLaren's firm. They then made the cylinder and crank-bearings in one self-contained whole, attached at one point to the boiler, and so

claimed to have overcome troubles of expansion. The arrangement shown in Figs. 5 and 6 (Plate XVI.) was evidently designed in recognition of a difficulty that had existed (and still existed) on the question of traction on roads by steam-engines, namely, the difficulty arising from having everything rigid as originally designed, experience showing the absolute necessity of having some spring or cushion between the engine and gearing and the ground. He did not understand the wheel shown in Fig. 5 (Plate XVI.), the blocks *c* seemed to be armed with a wrought-iron shield; there was a spring at the back, but whether that was an arrangement for tightening the blocks, or some other purpose, was not stated. With such a length of bearing of wood plugged into the wheels, after the wheels had been running some time they would become filled with grit, and how could the cushioning action then take place? He was rather disposed to think that a wooden plug alone would serve the purpose, and as a warrant for this view he might say how successful he had been in the use of wooden plugs driven into the travelling wheels that had to be submitted to severe road traffic—wooden plugs which experienced engineers thought would not last a month had been used for years. He was not going to criticize the arrangement shown in Figs. 7, 8, and 9 (Plate XVI.) beyond this, that they all knew if they were to have successful gearing, maintaining the true relation of the pitch-lines of the wheels was an important point. He was afraid that in traction-engine gearing the idea was, "make it strong enough and it will do."

There was a paragraph in the paper to the effect that it was necessary to free traction-engines from the legal restriction governing nuisance; he did not quite agree with that, he did not think they should be entirely freed. Besides the puffing of the engine, one nuisance was the rattling of the gearing. The gearing could not be free unless well designed, and the proper relation of pitch could not exist with the arrangement of springs as shown in Figs. 7, 8, and 9 (Plate XVI.). It seemed to him that the proper place for the cushion or elastic media in traction-engines was between the axle and the rim of the wheel. He realized that it was so in respect to autocars, and wishing to get the engine and gearing direct on the axle, he had designed a species of spring-wheel, which he thought would accomplish the results required. He took it that they first wanted to set down the problem to be solved, and then find the solution, and as the best place for the spring would be in the wheel they must provide for it. The spring action must be radial; they must not attempt to introduce springs which should have at one time a compression-strain, and at another time a tension, neither must they be liable to torsion

action. They must determine the direction in which the springs must work. The spring-wheel must absolutely prevent any torsional movement between the shaft and the outer rim. Although the outer rim and axle became eccentric—1, 2, or 3 inches—the outer wheel could still be driven without any twisting movement. In laying down these rules for spring-wheels he thought that he would secure Mr. McLaren's approval, and he thought that he could further assure him of having achieved that object.

Mr. McLAREN, replying to the discussion, said that the remarks of Mr. Head strongly confirmed his observations as to the necessity for a relaxation of legal restrictions. They were tied down by law to the wheel shown in Figs. 3 and 4, and were prevented from going outside the two styles, either smooth-soled or cross-barred, as shown in the diagrams, although they had every desire to improve on them. With regard to the block-wheel, the flexible pad was so called for want of a better name; rubber had been tried, but it was not found satisfactory, it squeezed out and required to be frequently replaced; fibre of one sort and another was tried until now poplar-wood packings about $\frac{5}{4}$ inch thick were used, and the wood alone was sufficient to take the injurious vibration off the traction-engine. The blocks would answer the purpose, if they were simply wedged into the rim of the wheel, but in the wheel described the blocks were free and not inclined to stick, as Mr. Holroyd Smith supposed, as the constant vibration kept them loose; the spring on the inside was a spring-washer, and intended to keep the blocks from dropping out as they travelled round. The blocks were 9 inches long when new, and the packing could be increased as they were worn down; when worn right down they were taken out and another poplar-wood packing put in.

With regard to the springs, they were all aware that efforts had been made during the last thirty years to mount road-engines on springs, but until a few years ago no really practical scheme had been devised. In 1876, when the Royal Agricultural Society's show was held at Birmingham, Messrs. Fowler exhibited a road-engine, fitted with a locomotive spring like that shown in the diagram, but differently arranged, and he thought that not more than one engine was made on that system.

Mr. Steavenson had mentioned a point overlooked in the paper, namely the question of gradients. The paper stated the load that might be carried up a gradient of 1 in 10, and that was about the stiffest hill they cared to negotiate in practice. If a road was 1 in 6 or 1 in 8, they would hesitate before advising the employment of traction-engines. An engine was running in Yorkshire on a gradient which, for a short dis-

tance, was 1 in 4½, but the bulk of the traffic was downhill: it had been necessary to place an arrangement on the front of the engine so as to keep the boiler level, and to make special provision for braking. This engine carried loads of 16 tons of coal and lime to the railway station; it could not take two full waggons on its return journey, but could take one full and one empty waggon by the adhesion of the wheels alone. Two waggons could be taken by using the winding-drum, with which every engine was provided. The design of engine-frame referred to by Mr. Holroyd Smith had been adopted on about forty engines. The engine was mounted independently of the boiler, and was mechanically perfect, but unfortunately it abolished the use of the steam dome.

He was very much pleased to acknowledge the vote of thanks so kindly awarded to him by the members.

Mr. A. GOBERT read the following paper on "The Gobert Freezing Process of Shaft-sinking":—

THE GOBERT FREEZING PROCESS OF SHAFT-SINKING.

By A. GOBERT.

In 1891, the present writer introduced into France the method of sinking shafts by freezing, a method which was then in its infancy. The writer resided at Pont-à-Vendin, near Lens, department of the Pas de Calais, during the critical months of the installation of the first freezing-plant applied to mining operations in France. It was found necessary to employ German labour, and the plant itself was supplied by a German firm. The cold-producing machine was of very simple yet solid construction, it has worked very well, and nothing better could be wished for in mining operations. Several English mining engineers have done the writer the honour to visit the works at Pont-à-Vendin, and a description by Mr. N. R. Griffith has been published in the *Transactions* of The Federated Institution of Mining Engineers.*

The operations were effected by means of an uncongealable liquid, but the writer's subsequent lengthy experience has induced him to dispense with this liquid, and to initiate the process of direct freezing, which will presently be described.

The Old Process.—The old process of freezing water-bearing strata comprises the sinking through these of a certain number of tubes known as freezing-tubes, and the circulation through these tubes of an uncongealable liquid cooled down to a temperature below 0 degs. Cent. (32 degs. Fahr.).

The freezing-tubes, closed at the bottom, are put down vertically in the water-bearing beds, and they are intended to freeze these to such an extent that pumping may be dispensed with, and that the strata may be trusted to hold together easily when they are being sunk through for the purpose of making a mining shaft or any similar structure.

Internal and External Pressure.—In the old method, the pressure within the tubes is invariably greater than the pressure outside them. The cause of this difference of pressure is as follows: the water-level of the country is below the soil-level, or at any rate not above it, while the

* Vol. ii., page 441.

refrigerator of the freezing-plant is necessarily placed at a higher level than that of the soil. Now, it is within this refrigerator that the uncongealable liquid is cooled down, and to it that the liquid continuously returns—to take up again a degree of cold equivalent to that which it gave up to the water-bearing strata, whilst it was passing along the freezing-tubes.

When great depths are reached the pressure of the liquid within the tubes becomes very high.

Drawbacks of an Excessive Internal Pressure.—An excess of pressure within the freezing-tubes necessarily brings about leakage of the uncongealable liquid, if there be any cracks in the tubes, or if the joints which unite these be not perfectly watertight. The liquid leaking out into the surrounding strata communicates to them its uncongealable properties, and if the strata are already frozen it dissolves the ice, forming an uncongealable mixture. It is needless to dwell on the serious consequences of a mishap of this kind.

Principle of Low Internal Pressure.—In order to obviate the difficulty to which the writer has just referred, he tried to hit upon a cold-transmitter whose pressure should be lower than that of the water outside the tubes, and anhydrous gaseous ammonia appears to fulfil this desideratum.

When anhydrous liquid ammonia is evaporated under various pressures the following temperatures are obtained :—

− 35 degs. Cent.	(	− 31 degs. Fahr.	)	corresponding to	a pressure of	0·90	atmosphere.
− 32	,,	(− 25	,,	)	,,	atmospheric pressure.		
− 30	,,	(− 22	,,	)	,,	a pressure of	1·15	atmospheres.
− 25	,,	(− 13	,,	)	,,	,,	1·46	,,
− 20	,,	(− 4	,,	)	,,	,,	1·84	,,

With ammonia vapour, therefore, we may always reckon upon very low pressures. If the tubes were not watertight, instead of the ammonia leaking out, the water from the surrounding strata would force its way in ; and so soon as the tube became mantled with a coating of ice, the water would cease to come in.

Evaporation of Ammonia in the Freezing-tube.—If simply a cold gas were introduced into the freezing-tubes the process of cooling down would be a very slow one. The specific heat of gaseous ammonia is 0·5084—in other words, a kilogramme of the gas, in being raised from the temperature of − 20 degs. to − 10 degs. Cent. absorbs 5,084 calories.

The latent heat of vaporization of ammonia has been recently determined by experiments. It is equivalent to 292·4 calories at 0 degs. Cent. (32 degs. Fahr.). The preceding figures show how much more effective a cooling agent is ammonia vaporized in the freezing-tubes than the circulation of cold ammonia gas through them.

In order to vaporize the liquid ammonia in the tubes, these have to be connected up with a suction and force-pump. This pump sucks in the gas and compresses it into a liquid, with the help of a condenser, and then forces the liquid into the freezing-tubes.

When the liquid is forced into a freezing-tube care must be taken so that it shall not fall to the bottom of the tube. This would happen if the injector used were a straight vertical pipe, open at the lower end. When the liquid falls as mentioned, being massed at the bottom of the freezing-tubes, it vaporizes very slowly, because the surface of vaporization is very restricted in comparison with the mass which has to be vaporized, and because it is in presence of a source of heat, which is equally small in comparison with the liquid mass.

Lowering of the pressure in the freezing-tube by means of the suction-pump would hardly obviate this difficulty, for the lowering of pressure would cool down still further the liquid which it is intended to vaporize. This being overcooled would become, as the specialists say, inert, or slack, by which they mean that it would evaporate with extreme slowness, being cooled so nearly to its freezing point; in other words, there is, in practice, a limit to possible lowering of pressures.

Serpentine Injector.—In order to avoid the fall of the liquid to the bottom of the freezing-tube, and to vaporize as much of it as possible in a given unit of time, the injector is made of the wavy or serpentine form in one plane (Figs. 1 and 2, Plate XVII.) or of the helicoidal form (Fig. 3, Plate XVII.). The writer's plan is to put the injector down nearly to the bottom of the freezing-tube.

The liquid, whose entrance into the injector is carefully regulated, falls slowly in a thin stream within this serpentine or helicoidal tube, and meets on its way a series of small orifices placed at various intervals along its valley-bed. By these orifices the liquid escapes into the freezing-tube.

The liquid constitutes, in point of fact, a very small, slowly moving streamlet, which every now and then disappears in part. These successive disappearances, and this slow rate of progression, are due to the particular form of the injector. The heat required for vaporizing the liquid is supplied by the surrounding soil or strata. It passes through the walls

of the freezing-tubes, and through the wall of frozen strata which soon surround the freezing-tube. The injector is closed at its lower end.

In the arrangement which has just been described, the injector-tube is concentric within the freezing-tube, and at no point are the two tubes in contact. But there is some advantage in placing the injector-tube against the wall of the freezing-tube, in such wise that there is a point of contact between the two tubes at every turn of the injector-tube. Fig. 4 (Plate XVII.) illustrates this arrangement, which facilitates the passage of heat from the soil or strata to the liquid that is to undergo vaporization, for the very sufficient reason that the metallic walls of the tubes are good conductors of heat.

Method of Regulating the Process of Freezing.—When the liquid ammonia reaches the freezing-tubes its vaporization is dependent on two causes: (1) the pressure within the freezing-tubes, that is, the suction-pressure set up by the refrigerator; and (2) the quantity of heat that is available and can be brought into the freezing-tubes.

The lower the suction-pressure, and the greater the quantity of heat brought in, the more rapidly will vaporization take place. If the suction-pressure be constant vaporization will simply vary according to the quantity of heat supplied; wherefore it will diminish in the same ratio as the quantity of heat will diminish. Starting from this fundamental principle, we deduce the method of regulating the speed of the freezing process.

Case of Constant Pressure.—Let us suppose that the pressure is constant, and let us further suppose that into a freezing-tube less liquid ammonia is injected than corresponds to the total vaporizing capacity of this tube, regarded in its entire depth. In other words, let us suppose that the quantity of ammonia injected per unit of time is less than that which, for the given constant pressure, could be vaporized in the same unit of time, thanks to the inflow of heat which can take place through the walls of the whole of the freezing-tube. What will happen?

The liquid ammonia will go down to a certain depth in the injector-tube and thence into the freezing-tube, and in the course of its travel to this depth it will be entirely vaporized, in such wise that not a single drop of liquid ammonia will reach the bottom of the freezing-tube.

The generation of cold will consequently take place only over a portion of the entire depth, and it is only in that portion that the freezing-tube will be surrounded by a jacket of ice. This ice jacket

diminishes the conductivity of the freezing-tube, and therefore the vaporizing power or capacity will be correspondingly diminished in that part of the tube which has become coated with ice, and at each successive descent the liquid ammonia will prolong its downward course in the liquid state.

This gradual descent of the liquid ammonia to the bottom of the freezing tube will lengthen little by little, until the liquid touches the bottom, when freezing will take place right along the tube.

As a general rule, then, the process of freezing can be so regulated as to freeze, first of all, the upper measures. The mass of ice will then spread from top to bottom. The whole power of the engine will at first be applied to the freezing of the rocks near the surface. Thanks to this arrangement, sinking can be started much sooner than in the case of the uncongealable-liquid process. Simultaneously with the sinking operations, fresh strata will successively freeze and allow of continuous sinking.

Verticality of the Freezing-tubes.—While sinking thus deeper and deeper, the verticality of the freezing-tubes may be checked by the help of the thermometer and of small horizontal headways driven through the frozen mass.

If it be ascertained that a freezing-tube is shifted from the vertical in such a manner as to spoil the success of the operation, the difficulty can be met in the first stages of the work. In the old system, the determination of the verticality of the freezing-tube can only be proceeded with at a much later stage.

Excess of Ammonia.—Let us now suppose that an excess of liquid ammonia is allowed to enter the injector-tubes, say a quantity such that, with the available suction-pressure, the inflow of heat through the walls of the tube will be inadequate to produce complete vaporization. What will happen then?

A certain quantity of liquid ammonia will reach the bottom of the freezing-tubes, and will remain there in the liquid state. This will not be a very serious matter; it will be equivalent to the temporary immobilization of a certain quantity of liquid, and the vaporization will continue at its maximum intensity.

Let us hasten to add that this state of things cannot arise if the refrigerating apparatus be properly regulated, and if its working be carefully watched.

Signs by which the Admission of Liquid in Excess will be recognized.—The assumed fall of liquid ammonia would be immediately made known by a circumstance which could hardly escape notice: the pressure-tube, going from the compressor to the condenser, would cool down very markedly before any considerable quantity of ammonia could fall.

The explanation of this physical phenomenon which is constantly taking place in all refrigerating engines is as follows:—

Ammonia Mist.—Let us suppose that into the vaporizing apparatus of a refrigerating engine more liquid is introduced than the quantity which corresponds to the vaporizing capacity. What will happen? A portion of this liquid will remain liquid, and will take the form of very finely divided drops. These minute drops, commingled with the vaporized portion, will cause the whole fluid mass to constitute a mist or fog, and as such it will reach the compressor, where it will be compressed.

We must remember that in the compressor no liquefaction takes place, but only a compression of the gas with liberation of heat.

Lowering of the Temperature of the Compressor.—When the gas is charged with liquid drops the heat liberated by its compression serves to vaporize these drops. This vaporization brings about a very considerable lowering of temperature, both in the compressor and in the tube going from the compressor to the condenser. Let us suppose, for example, that we have to deal with a compression-tube which, in ordinary working (that is, without admission of ammonia in excess), would have a temperature of 25 degs. to 30 degs. Cent. (77 degs. to 86 degs. Fahr.). Let us further suppose that liquid ammonia is admitted in excess, then the temperature of the tube will immediately begin to go down, and in certain cases it may go down as low as 10 degs. or 12 degs. Cent. (50 degs. or 53 degs. Fahr.).

Ease with which the Working of the Engine can be Regulated.—We are, then, in possession of a very simple and an absolutely trustworthy method of regulating the working of the engine. It will be easy to prevent the fall of liquid ammonia, and the vaporizing capacity of the tubes may be utilized to the full if the apparatus available be powerful enough to liquefy all the ammonia vapour produced in the freezing-tubes.

Explanation of Figures 5, 6, 7, 8, 9, 10, and 11.—Figs. 5 and 6 (Plate XVII.), represent a refrigerating-works, planned on the supposition that it is not intended to use the uncongealable liquid.

Fig. 5 (Plate XVII.) represents a shaft, the bottom of which alone is frozen—the writer has assumed the case of a shaft tubbed and full of water, such as those at Cannock and Huntington, in Staffordshire. The freezing-tubes, placed within the tubbing, have transmitted the cold to the bottom without freezing the water in the upper portion of the shaft. This water is pumped off so soon as the bottom of the shaft is frozen, and the tubbing remains perfectly sound.

Fig. 7 (Plate XVII.) represents the floor which closes the mouth of the shaft, and through which the waste dug out is sent up.

Fig. 8 (Plate XVII.) shows the manner in which the pipes for distributing and collecting the ammonia are arranged. It is so contrived as to leave the central portion of the shaft entirely free.

Fig. 9 (Plate XVII.) shows the putting up of a second tubbing of smaller diameter than the original tubbing.

Fig. 10 (Plate XVII.) shows the joint used for the freezing-tubes. Its essential part is an internal jacket indicated by dark lines of shading. This jacket bears on its external surface a circular rim having the same external diameter as that of the tubes which are to be joined together. The circular rim allows of a distinct joint being formed with each tube by means of two small leaden discs tightly wedged in between the rim on the one hand and the end of each tube on the other. The tubes are so cut that their ends assume a conical form. The line *a a* shows in section one of these conical surfaces. The circular rim of the jacket also presents two conical surfaces which are inclined inversely to the inclination of the end of the corresponding tube. The line *b b* shows in section one of these conical surfaces of the rim. Thanks to this double and inverse conicity of the rim and of the ends of the tubes, the two leaden discs are very tightly wedged in between the aforesaid rim and tubes, and in this manner the joints are made perfectly taut and the external diameter of the tubing is kept uniform throughout.

Conclusions.—The advantages of the direct-freezing method may be summarized as follows:—

1. The uncongealable liquid is dispensed with.

2. The apparatus for cooling the aforesaid liquid is also dispensed with.

3. High pressures within the freezing-tubes are avoided.

4. Greater economy in the use of the refrigerating engine, thanks to the suppression of the intermediate agent or middleman—the uncongealable liquid.

5. The possibility of utilizing the entire refrigerating power of the engine, first of all, in freezing the upper portion of the strata through which it is desired to sink.

6. The possibility of starting sinking operations much earlier.

7. The possibility of checking much more quickly the verticality of the borings.

8. The possibility of freezing the bottom of the shaft without freezing the surface.

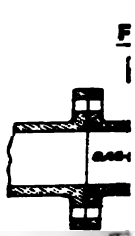
9. The possibility of putting freezing-tubes down a shaft which is tubbed and full of water, so as to freeze the bottom without making the tubbing burst.

10.—The possibility of producing much lower temperatures, and of freezing salt-water.

The PRESIDENT, in moving a vote of thanks to the writer of the paper, remarked that Mr. Gobert was a Belgian mining engineer, and that they were honoured by the presence of the Belgian minister, who had attended specially to hear the paper read. English engineers were always so well received in Belgium that it was a pleasure to welcome their Belgian friends in return. Mr. Gobert appeared to have made out a good case for his improved process of shaft-sinking.

Mr. A. L. STEAVENSON asked whether Mr. Gobert considered that his process would compete with the Kind-Chaudron process for sinking through rocks under water; or was it simply intended for going through superficial or other soft strata? In South Durham, rock-salt was found at a depth of 1,000 feet, and the first 100 feet consisted of beds of sand with water, and he thought that the Gobert process would be very useful. He believed that it was stated in a previous paper that 100 days would be required for the freezing of about 100 feet of strata; that was rather a long time to wait before beginning the sinking operations. The cost of the system would, of course, depend on the particular section, and perhaps Mr. Gobert could give the members some general idea of the cost of sinking, say, 100 feet by his system.

Mr. GOBERT, referring to the Kind-Chaudron system, said that he presumed all the members would be familiar with the process; the actual sinking was with a trepan—the hole being made vertical of the required



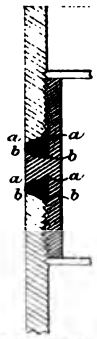
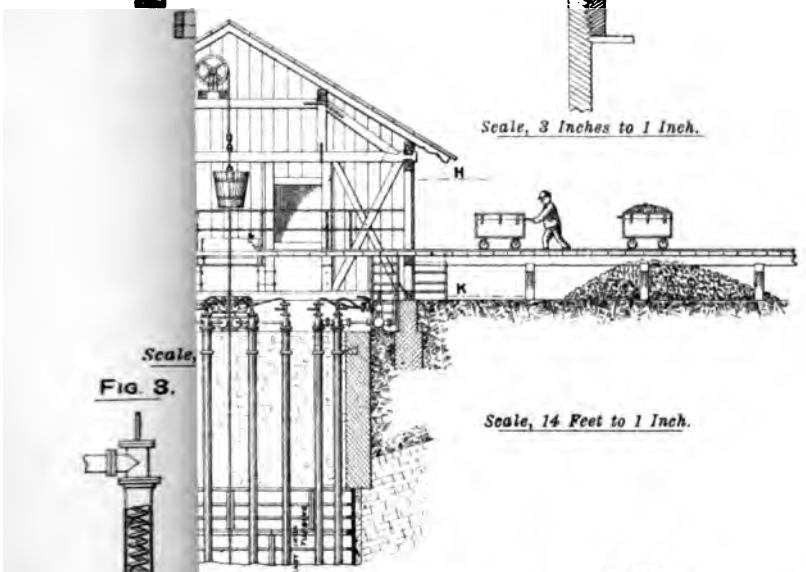


Fig. 10.

Scale, 3 Inches to 1 Inch.



Scale, 14 Feet to 1 Inch.

Scale,

Fig. 8.

Scale, 5 Feet to 1

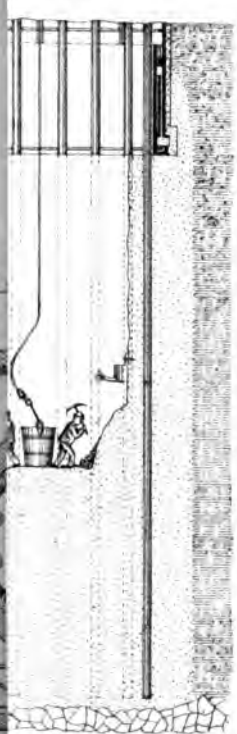
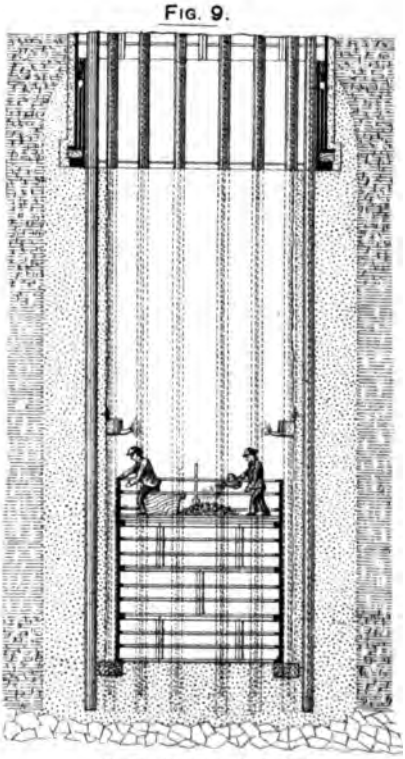


Fig. 9.



Scale, 14 Feet to 1 Inch.

diameter, and the water was left in this hole to prevent the outflow of quicksands. If the boring were made through solid rocks which contained much water, then the Kind-Chaudron would work successfully; but if it had to go through soils, sand, and other strata which were not solid, or were so fluid that even by leaving the water in the hole the wall of natural soil would not remain vertical, but would fall, the Kind-Chaudron process presented great difficulty, and if there were 100, 200, or 300 feet of real mud without any consistency nothing could be done by means of that process. There were cases where it would be impossible to sink with the Kind-Chaudron process, and it was in these that the Gobert freezing process had a great future. One great feature in favour of both freezing processes against the Kind-Chaudron is the facility of making the backing or wall of concrete outside the tubbing. One great advantage, special to the Gobert freezing process, is the possibility of sending cold to a depth of say 3,000 feet without producing inside the tubes a pressure higher than twice the atmospheric pressure. There is no limit of depth to the application of the Gobert process. The finished cost was approximately £40 per foot of shaft for a large shaft, and he was certain it would not cost more. In the old methods of sinking, shafts had been begun in the hope that they would be finished in a certain time and at a given cost, but both time and cost had been more than doubled. With his new process both time and cost could be estimated with certainty. The freezing progressed with the sinking, and it was claimed for his process that it required less machinery, less working expenses, and less time than the old method of shaft sinking with uncongealable liquid—perhaps three-quarters the capital and one-half the time and working expenses of the old method of congealation. The plans (Plate XVII.) attached to his paper illustrated the application of his process to the sinking of the shafts at the Cannock and Huntington shafts, which had been abandoned in 1875 after the insertion of the tubbing by the Kind-Chaudron system, owing to the failure of the moss-box at the foot of the tubbing.

The following paper by Mr. H. W. Ravenshaw on "Precautions Necessary in the Use of Electricity in Coal-mines" was taken as read:—

PRECAUTIONS NECESSARY IN THE USE OF ELECTRICITY IN COAL-MINES.

By H. W. RAVENSHAW.

Although the use of electricity for lighting and the transmission of power in coal-mines is becoming more general, and many of the plants have been running for some years, no serious accidents or explosions have, within the experience of the author, been traced to its adoption. In some districts, however, where the seams are very fiery, colliery proprietors have refrained from adopting it, preferring to use less efficient or convenient methods, than to run the risk of an explosion.

Some writers on this subject have inclined to the view that there is little or no risk of the ignition of gas, by the spark caused by the rupture of a cable through which the current is flowing. This, however, remains to be proved, and it is much better to guard against a possible danger than to run the risk of losing even a single life. As a matter of fact, the risks are few and easily guarded against, and there is no reason why electric motors should not be used in the most fiery mines, if proper precautions be taken in putting down a suitable plant and keeping it in an efficient state of repair.

It is proposed in this paper to offer a few suggestions, the carrying out of which may serve to minimize the risk both from shock and fire.

Shocks.—A very unpleasant shock can be obtained from a 600 volts circuit, even on dry ground, and the results might be very serious to anyone who was standing on a wet floor or in water. A shock may also cause a man to fall without directly injuring him, and for this reason gear-wheels and other moving parts should be well guarded in the neighbourhood of any switches, resistances, or motors, which might have to be handled during the running of the machinery. All parts of the electric circuit should be covered, so that it is not possible to touch them without deliberately taking off the protecting covers, and the metal cases of switches and junction-boxes should always be connected permanently to earth by a stout wire, either through the tramroad rails or to water-pipes in the vicinity. Motor bed-plates should also be well earthed, especially if the machines be fixed on timber foundations.

An instance has come before the author where a shock was obtained from a hauling-rope, the hauling-engine having been fixed to heavy timbers in a very dry pit, and an accidental contact having occurred between the motor and the frame of the hauling-engine.

Where parts, such as brushes, have to be handled while the circuit is alive, a sound dry timber floor with perhaps a rubber mat, and a wooden handrail for the man to steady himself by, are the best protection. India-rubber gloves are most uncomfortable and clumsy, they are liable to be pierced by small chips of metal, in which case they are worse than useless, and, except in awkward situations, they are not to be recommended.

Even with a low voltage it is possible to obtain a very severe shock, owing to the high pressure which is momentarily obtained in breaking the circuit of an electro-magnet. The author cannot give any instance where loss of life has been traced to this form of shock, but the experience of anyone who has accidentally broken the circuit of even a small magnet, and whose body has remained as a shunt to the break is one to be remembered for a lifetime. Great care should therefore be taken in handling the wires connected to the field-magnets.

The question of prevention of shocks, although little danger to life is presented, is of importance, as the machinery is much more likely to be well looked after if the attendant be not afraid to touch it.

Main Conductors.—One of the principal characteristics of electric power is the enormous amount of heat which can be concentrated into a small space, and consequently the high temperature which results. These conditions can be obtained either by an arc being formed, as in the case of a broken wire, when a considerable amount of energy is expended in the air-gap; or by a short circuit, where practically the whole of the power which can be generated is concentrated in a comparatively small part of the system.

The result of a short circuit, extending as it does to the generating-station, is easy to deal with, and fuses or other automatic devices can be employed to break the circuit before much damage is done. In certain cases, however, a partial short circuit may cause great heating, although the current due to the reduced resistance may not be sufficient to blow the fuses at the generating-station.

It is imperative that the very best materials and workmanship be put into the cables. The difference in cost between the very best and the cheapest is so small that it is never advisable to even consider the desirability of using a cheap cable.

Where the shaft is wet, the cable should be run in cast or wrought-iron pipes having joints and junction-boxes made thoroughly watertight. These protecting pipes should be carried as far into the mine as is necessary to get clear of the water. Where, however, there is no water, armoured cables may be used, care, however, being taken that they cannot be readily damaged by any accident to the cage.

The usual method of carrying the cables from the bottom of the shaft to the motor is to suspend them from the timbers by means of insulators. In fixing them in this way there is great danger of the cables being damaged either by falls of the roof, breaking of the timbers, or by run-away waggons. In most cases, however, the cost of protecting the cables would be so great that this simple method is to be preferred, especially as they are accessible for inspection and repair. Several schemes have been suggested and some have been tried for preventing the occurrence of a spark or flame on the breakage of a cable. None of these arrangements has been generally adopted, and it is very doubtful whether any device can be relied on whose action must necessarily depend on the accurate adjustment of comparatively delicate apparatus.

Personally, the author is very much in favour of the use of concentric cables, the external conductor being connected to earth at frequent intervals if not continuously. There are some drawbacks to this arrangement, especially in the switches and motors, but these can be guarded against, and the risk from fire in case of damage to the cables is enormously reduced.

In the concentric cable, one conductor is thoroughly well insulated, and the other is stranded over the outside of this insulation. In some cases the outer conductor is used for the protection of the cable, no other insulation being used on the outside. It is, however, advisable to make the cable perfectly watertight by means of leaden covering, and again to protect it with iron armouring. In damp places it may be necessary to cover the armouring with insulating material to prevent corrosion from electrolysis.

A number of installations have been fitted up on this system, the outer or return wire being uninsulated or connected to earth. This, of course, has the disadvantage that the chance of breakdown from defective insulation is doubled: in fact, on the cable being damaged a short circuit will be almost certain to occur on the particular section affected. This drawback is, however, really counterbalanced by the fact that defects at once show themselves, as the safety-fuse breaks the connexion in a part of the mine where the resulting spark can do no harm.

It does not appear possible for the concentric cable to be broken without the inner wire coming in contact with the outer, causing a short-circuit, and cutting off the current at the fuses before the wires are severed, and preventing a big flash at a place where a fall of roof may have liberated gas.

Junction-boxes.—Branches and joints should always be made in cast-iron junction-boxes in order that soldering may be avoided. These boxes should contain good solid terminals mounted on slate or porcelain, the opposite poles being well separated from each other. The cables should be taken through stuffing-boxes, and the wires so fixed to the terminals that it is impossible for the cables to be drawn out accidentally. The boxes must, of course, be water-tight, the covers having faced joints so that loose packing is not required, as this always gets displaced in time.

Switches.—Where a branch occurs, a switch should be fixed in order that the circuit can be broken for testing or in case of accident. With concentric wiring, a single-pole switch is only required, which will break the circuit of the inner wire. In double wiring, however, both poles should be provided with switches.

Switches must always be so made that there is no fear of an arc being started on breaking the circuit, and it is most important that with double-pole switches the parts of opposite potential operate in quite separate compartments, having a division of slate or porcelain between them. The break should be at least 6 inches long on each pole.

Switch-boxes should be lined with slate to prevent an arc being started on to the metal case. It should be absolutely certain that, when the switch is turned off, the circuit is entirely broken. It is difficult to conceive a more unpleasant predicament than for a switch to take charge and start an arc on its own account instead of breaking the circuit. This has actually occurred in practice where the switches have been designed so as to be neat and compact and efficiency of working has been overlooked. It is quite easy to make a switch which will always perform its functions without risk of failure, and no expense should be spared in this part of the plant.

Where switches are enclosed in metal cases, they must be perfectly air-tight. Stuffing-boxes for the cables are always liable to leak, and it is advisable where there is gas, to have a separate box carrying the terminals, into which the cables can be brought, the connexions to the inside of the switch being sealed up with bitumen or similar material.

Resistance-frames in connexion with starting and regulating-switches are always liable to cause contact with the earth. When porcelain insulators are used, the frame to which they are fixed should also be insulated, so that in case of a broken insulator the wire which it has supported will not make contact to earth.

Wire coils are often used for resistances, and are usually flexible and liable to knock against each other or against their supports. They should be so spaced that it is impossible for them to touch surrounding objects, as a more or less dangerous spark might be caused by adjacent coils coming in contact. All resistances should be amply large enough to carry all the current that it is possible to put through them without over-heating. In some cases, as on coal-cutters, it would be impossible to fit resistances which would be capable of carrying the current continuously. In this case the switch must never be left in an intermediate position: in fact, it should be made so that it is impossible to leave it in any position except wholly on or wholly off.

Water-resistances in which the circuit is broken between the surface of water or a weak alkaline solution, and a metal or carbon contact, are very suitable for starting motors gently, as they can be made so that there is no spark between the contact and the surface of the water. As, however, the water is decomposed, these switches should not be enclosed in such a way that the explosive gases generated can accumulate. This form of switch is very simple and is not liable to get out of order.

Motors.—Although the electric motor is now fairly well standardized, it is very important that the type of machine chosen is suitable for the work it will have to do. Where a large number of motors are in use on the same installation, it is usual to put down either shunt-wound or compound-wound machines which work in parallel. Very fair regulation can thus be obtained, and if the cables be properly proportioned, the starting or stopping of any one motor should not affect the speed of any other.

Where, however, only one motor is used, it is advisable to have both motor and dynamo series-wound. If these machines be properly designed, the speed regulation of the motor, given a regular speed of the dynamo, will be good, and this combination has the great advantage that, when the motor is switched off, the dynamo gives no volts and takes little or no power.

Series-wound motors have in many cases been used in parallel with other machines for driving pumps. These work well so long as the load is

constant, but the motor tends to race if the pump loses its water, and it is advisable for this reason to use a compound-wound motor designed so that it will start readily under load, and will not run away when the load is taken off.

Motor Magnets.—With a series-wound motor, the field-magnets are very simple, having a comparatively small number of turns of thick wire, which are not liable to be broken or to get displaced. Many of the most successful plants, both at home and abroad, are arranged on this plan, and it is at times advisable, when there are several motors, to provide an independent dynamo for each. This arrangement has also the advantage that the motor starts very steadily and without shock.

Shunt-wound and compound-wound motors are formed with thousands of turns of fine wire, and when the coils are connected across a circuit having a pressure of say 600 volts, the wires on adjacent layers have a considerable difference of potential between them. This is a source of breakdown, as, if the insulation be defective, a partial short circuit will occur, which may in time burn through the fine wire. In fact cases have occurred where an arc has been started in a shunt-coil and the wire very badly burnt, if not destroyed. For this reason the wire must be thoroughly well insulated, and adjacent layers separated by an effective insulating material.

The break down of the insulation between the wire and the frame of the machine is another source of trouble. The author has seen otherwise well-made machines with only a sheet of Willesden paper between the metal former carrying the coil and the wire itself. There should always be at least $\frac{1}{4}$ inch space between the wire and the metal parts of the machine, mahogany or teak being used to separate the winding from the metal former.

When the circuit of an electro-magnet is broken, a very high pressure is momentarily produced, which will find out any weak places in the insulation, besides causing a bad spark where the circuit is disconnected. With high-tension shunt-magnets, the pressure at breaking is enormous. This danger can be avoided, however, by using a switch which will insert a resistance in parallel with the magnet to be broken, just before breaking, the resistance being left in parallel so that the magnet-coil can discharge itself at its leisure.

If the resistance be properly proportioned and wound non-inductively, that is, so that it does not tend to resist a sudden flow of current, the spark at breaking the circuit of a magnet weighing many tons can be reduced to very small dimensions.

In certain cases the switches can be so arranged that the magnets are permanently left in parallel with the armature. It is, however, always advisable, with large motors, to use a switch and resistance as above described, as it is usual to excite the magnets of the motor a minute or two before the armature current is turned on.

Series-magnet coils will also cause sparking at the switch when the motor is cut off, consequently both motor and dynamo should be fitted with a resistance permanently connected in parallel with the series-magnet coil. This resistance absorbs very little power and reduces the spark on breaking the circuit to a very small amount.

By taking the above-mentioned precautions, the sparking at the switches can be reduced to a mere speck and the danger from breakdown is practically eliminated.

Motor Armatures.—The most important, and unfortunately the most complicated, part of a continuous-current motor is the armature, but although few radical alterations have been made in the last ten years, many details have been improved, and, given good workmanship, an armature should run without repairs for several years.

The use of geared wheels has been one of the most fruitful causes of expense, the rapid vibrations transmitted to the armature being certain to eventually destroy it.

In certain cases where the speed of the armature is below 500 revolutions per minute, and where the construction is particularly good, an armature will run for many months without repairs, but wherever it is feasible belt-driving or worm-gearing should be used for the first reduction of speed.

It is a remarkable fact that in many cases under heavy vibration an armature gives way mechanically while the insulation remains intact. Consequently the armature and commutator should be fixed to the shaft by the most efficient mechanical means possible.

Two forms of armature are commonly used, having respectively the Gramme or the drum-winding. In the former, the wires pass through the centre of the armature, the iron core being a hollow cylinder supported on gun-metal arms. This type of armature has been in very general use in collieries, it being considered more suitable for high voltage than drum-winding.

The drum-armature, has been used a great deal lately, and has many advantages which generally outweigh those of the Gramme. The construction of this armature necessitates the winding of wires, having the

full voltage between them, side by side along the periphery, and unless these are well insulated, a short circuit may occur between them.

In the Gramme-winding, however, there is a much lower voltage between wire and wire, and in small armatures it is possible to repair a burnt-out coil in a comparatively short time. When, however, large armatures are Gramme-wound, the space inside the core for the wire has to be made as small as possible to keep the size of the machine within reasonable limits, and wires having considerable difference of potential between them are packed together inside the armature. In fact, in case of a burnt-out coil, it is almost always necessary to rewind a sixth or a quarter of the armature.

In the ordinary wire-wound drum-armature there is an accumulation of wires at the end where the various sections cross one another, but during construction it is very easy to insulate these so that there need be no fear of short circuit. Drum-armatures are, however, being made in which the wires are brought round the end of the armature symmetrically, avoiding contact between wires of opposite potential.

Apart from a somewhat greater liability to short circuit, and in some cases less facility for repair, the drum-armature has many advantages over the Gramme, some of which are enumerated below. The armature can be made smaller and lighter for the same work. There is much less liability to spark at the commutator. The armature is a good deal cooler especially in the larger sizes (this is most important where enclosed machines are used); and mechanically the armature can be made stronger, the charcoal-iron plates being keyed direct on to the shaft without the intervention of a gun-metal spider.

In the estimation of the author, however, the greatest advantage lies in the fact that on the occurrence of a short circuit a drum-armature stops at once and refuses to turn round: this causes a great rush of current which blows the fuses and disconnects the circuit at once. As the current is cut off automatically, a drum-armature is seldom badly burnt, as the time during which the current is flowing through the short circuit is too short for much damage to be done. With a Gramme-winding, however, the armature may continue to revolve for a long time after a short circuit has occurred, in which case the armature will be badly burnt, and dangerous sparks or flames given off.

Enclosed Motors.—In fiery mines it is usual to enclose the armature or the commutator in gas-tight covers, so that an accumulation of gas may not be fired by the sparking at the commutator. It has been con-

tended that it is impossible to fire gas from these sparks; but although a good dynamo will run perfectly at the brushes, there is always a chance of sparking, owing to the brushes chattering, or to a damaged section of the commutator.

The author has designed a large number of enclosed motors during the last few years, and in his opinion, so long as the covers are really well made, and the joints are kept perfectly gas-tight, they will afford ample protection. There is, however, a great danger of the covers being taken off, or the joints being improperly made, and it is a question whether they are to be relied on.

In large motors there is some difficulty in getting sufficient surface to dissipate the heat which is transmitted from the armature to the covers, and water or compressed air circulation has been used with good results. Where compressed air is available, a constant pressure may be kept up inside the covers, which will effectually exclude any gas which may be about. In any case, it is advisable to thoroughly ventilate the chamber in which the motor is placed, and if this be done, it is doubtful whether it is necessary to enclose the armature. The greatest safeguard against accident is, however, good supervision and careful daily testing.

Testing.—It is most important that the insulation of the cables and the motor be tested daily before starting. This can easily be done from the generating engine-room by the use of testing sets, which are at present in the market, and is of the utmost importance for the safety and efficiency of the plant.

It is needless, perhaps, to say that there should be an efficient system of telephones or signals between the engine-room on the surface and the motors.

In advocating the use of concentric cables and drum-armatures, it must be pointed out that both of these systems have been in extensive use in collieries for some years, and their efficiency has been proved. By their use any defect at once shows itself, and the supply of current is automatically cut off before a fire can occur.

As continuous-current motors have been almost entirely employed for the transmission of power in this country, it has not been thought advisable to discuss the use of alternating-current motors. In many instances, however, the precautions required are the same in each case, especially with respect to the main conductors, switches, and the insulation of the motors.

Finally, the experience of some years of working has shown that the transmission of power by electricity can be safely adopted in collieries if reasonable precautions be taken, and a plant be put down of sufficient dimensions to do the work without being overloaded.

Mr. CHARLES SNOW (Rotherham) wrote that he could fully endorse Mr. Ravenshaw's statement respecting the value of passing compressed air through the gas-tight cover of enclosed motors. Compressed air had been used for the last three months at Hickleton Main colliery, and during that period, no difficulty had arisen from heating of the commutator, although the motor worked continuously from 6 a.m. to 10 p.m. The air is used at a pressure of 10 lbs. per square inch, and a very small quantity serves to keep the machine cool. The armature and commutator are both enclosed, the air is passed through the machine, and the outlet is covered with ordinary safety-lamp gauze. The plant can develop 100 horse-power.

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) wrote that Mr. Ravenshaw had pointed out in his paper the danger of sparking at the commutator, and stated that he had designed a large number of enclosed motors, but, at the same time, he casts great doubt on their safety. He (Mr. Stokes) thought that such motors were objectionable for the following reasons :—Their safety depends upon the covers being kept gas-tight, and the slightest neglect of a bolt or fastening, or a bad joint, is fatal to their efficiency. The heat generated inside the covers is great and detrimental to the economical working of the motor. The cubical capacity of the cover is so large that if filled with an explosive mixture and fired by a spark, it might burst the cover unless sufficiently strong to resist the explosive force. The opening of the cover while the machine is running, or running the machine without the cover, and the increased weight and size due to the covering are strong objections to the covering in of the motor.

Mr. Ravenshaw did not appear to be aware of the motor described in the *Transactions*,* in which a motor with hollow commutator was described. In that motor, the brushes are placed inside the commutator, and the commutator when at work is a small flame-tight chamber, which, after the bushes are inserted, cannot be exposed to the

* *Trans. Fed. Inst.*, vol. iii., page 192.

atmosphere whilst the motor is running, nor can the motor run until the brushes are securely fixed inside the flame-tight chamber of the commutator. The enclosing or locking arrangement should not be dependent upon a workman, but should be the governing security with regard to the machine being at work or at rest. Such motors, with hollow flame-tight and dust-tight commutators, have been running for years in a fiery mine. They have been exhaustively tested in explosive atmospheres, and with such motors, no danger can arise from sparking at the brushes.

Mr. A. W. BENNETT (Leeds) wrote that, whilst in the main agreeing with Mr. Ravenshaw, he was inclined to think that both the positive and negative leads should be well insulated, and the earth or a bare conductor should not be used, and that a simple device for detecting and measuring any leakage to earth from either should be fixed on the main switch-board, and possibly, too, on any branch switch-boards or in junction-boxes. This opinion of course applied to lighting and power circuits where 100 volts or over was the normal pressure.

The reasons for this opinion are as follow:—(*a*) Shocks are most likely to be received (provided the installation has been carried out with reasonable precautions) at the generating dynamo and at the switches. He had experienced unpleasant (though by no means serious) shocks from 100 volts dynamos, whilst from others no such shocks could be obtained, even by entirely breaking circuit, unless, however, both ends of the break were held or came otherwise in contact with the body: the reason being a leakage to earth in the first case, although it might require a very sensitive galvanometer to detect it. Such an earth from one wire, even if the other end were fully earthed, would not blow a fuse unless the margin in the fuse were cut very fine and the working current quite constant. (*b*) He would imagine that a leak or arc across to earth in a switch junction-box or resistance might cause considerable heating without being sufficient to blow the fuses controlling that circuit. (*c*) It was quite possible for a leakage from a dynamo circuit when earthed to ring a bell, also earthed, and to give a false signal; whilst under circumstances by no means improbable, a dynamo circuit earthed and telephone circuit earthed produce such a scream or noise in the telephone as to render it useless.

On the whole, he considered Mr. Ravenshaw's paper well worthy the attention of mining engineers, and would take the liberty to refer them to his (Mr. Bennett's) paper, which related to the same subject.*

* *Trans. Fed. Inst.*, vol. vi., page 366.

Mr. L. W. DE GRAVE (Derby) wrote that Mr. Ravenshaw had presented a very formidable list of possible accidents which might arise from the use of electricity in mines, but he was glad to see that he prefaced his remarks by saying that "no serious accidents or explosions have within the experience of the author, been traced to its adoption."

There was, in his opinion, no cable so safe or good as the concentric with a bare outer conductor consisting of galvanized iron wires of the same capacity as the inner, run down the shaft in an iron pipe as described by Mr. Ravenshaw. He could not agree with him, however, as to the advisability of using lead as a means of protection from water, nor as to the earthing of the dynamo and motor-frames, for which he preferred to take extra precautions in insulation. With a concentric cable having the outer conductor properly and judiciously earthed no shock would be felt nor would electrolysis occur.

One of the principal points to be observed in erecting an electric plant underground was to fix the cables so that they would fall if an undue strain came upon them, and thus avoid any danger of breakage from falling roof. When broken down the cable can, of course, be crushed, but with a concentric iron outer conductor the outer would be forced into contact with the inner, forming a short circuit and blowing a fuse. He (Mr. de Grave) was surprised to find Mr. Ravenshaw was of opinion that the risk of breakdown with a concentric cable is doubled—it would be much nearer the mark to say that it is reduced to one-tenth. The insulation cannot (except wilfully) be damaged unless the outer conductor be destroyed (he was now referring to cables with a bare galvanized iron outer conductor). This statement was based on his own experience, and was, he believed, a generally accepted fact.

Switches he looked upon as necessary evils, and preferred to let the one at the motor do the work without creating weak points at branch-roads and gate-ends. His (Mr. de Grave's) views on the form of winding, suitable for various requirements, he had already expressed in the *Transactions*.* He might, however, add that shunt coils for high pressures are generally wound in sections with 150 to 200 volts across each section. Water-resistance switches for the starting and stopping of motors are excellent theoretically, but practically, they have two defects: (*a*) it is impossible to keep them insulated from earth; and (*b*) provision must be made for carrying off the steam and gases which are generated in considerable quantities unless very large electrodes are used.

* *Trans. Fed. Inst.*, vol. ix., page 198.

Mr. Ravenshaw's method of getting over the induced spark on breaking a magnet circuit introduced an extra resistance, and a complication on the switch which were things to be avoided. Personally, in the case of shunt-motors, he left the shunt on all day, unless long stops were made, the shunt being broken, when required, in parallel with the armature; in series motors, he would short-circuit the series-winding on itself immediately the main circuit was broken. The resistance Mr. Ravenshaw referred to in parallel with the series coil, besides being a complication, caused the motor to run faster, allowance for which had to be made in arranging the gearing.

He was glad to see that Mr. Ravenshaw was of the same opinion as himself as to the use of belts* for gearing motors and dynamos, and that he was inclined to prefer drum armatures. A machine with a well constructed drum armature is much more efficient as an engineering work than one with a ring armature.

There was a very prevalent, and at the same time false, impression that in order to make a motor safe in an explosive mixture all that was necessary was to enclose it—quite irrespective of the cubic contents. It was most essential that the volume should be sufficiently small to prevent disruptive force, and at the same time sufficient to prevent the flame connecting with the outside atmosphere. The above principle is carried into practice in the Davis and Stokes motor tested and described by Mr. Deacon in the *Transactions*.†

Mr. HENRY DAVIS (Derby) wrote with regard to Mr. Ravenshaw's remark that "some writers on this subject have inclined to the view that there is little or no risk of the ignition of gas, by the spark caused by the rupture of a cable through which the current is flowing. This, however, remains to be proved." He was glad to see that Mr. Ravenshaw preferred to consider that it was desirable to provide against the possibility of firing gas through the breakage of a live wire, for there were cases on record where a spark, even from the very low tension-current of electric signal-wires, had fired gas, with the result of miners being burned. Two cases to his knowledge had been reported to H.M. Inspectors of Mines.

He agreed with Mr. Ravenshaw as to the advantages of employing concentric cables with a bare and earthed armouring, which conveys the so-called return current; but he could not acknowledge that "drawbacks" occurred. The armouring protected the inner conductor from mechanical injury; and in consequence of earthing the return current throughout

* *Trans. Fed. Inst.*, vol. ix., page 198. † *Ibid.*, vol. iii., page 192.

the system, the effect of a shock was reduced to a minimum. He preferred to carry the cables down a shaft (wet or dry) in iron pipes to avoid mechanical injury from falling coal or other causes. Should a fall of roof occur, and the cable became severed, a short circuit took place, and the nearest fuse was blown without the dangerous flash, as when a cable was accidentally severed in one or both of the two-wire systems. He could not agree with the author that the concentric system increases the chance of breakdown from defective insulation. Such a statement was not borne out by facts. The risk of short circuits, and therefore the risk of fire, is minimized to a great extent, and the cost of erection is reduced. The first cost is not increased, and, if he might venture into the region of prophecy, he might say that the concentric system would be very universally adopted for all power plants of any magnitude and considerable voltage in the near future.

Mr. Ravenshaw stated that "where switches are enclosed in metal cases, they must be perfectly air-tight," but as he did not give any illustration of an air-tight switch, he (Mr. Davis) could not pass any opinion, but it was difficult to conceive how a switch could be made so as to remain perfectly air-tight out of the control of an electrical engineer. He preferred a switch having the smallest possible air-space, and the joints constructed so that a possible firing of gas may not communicate with the outside air; that is, all joints should be flame-tight on the principle of the Davy gauze lamp.

There was undoubted proof that the sparking at the brushes of motors would fire gas. Experiments had been conducted at various places where ordinary coal-gas has been readily and repeatedly fired. He might mention Mr. C. E. Rhodes' and Mr. Maurice Deacon's experiments as confirming this statement.

Mr. Ravenshaw stated that he had designed enclosed motors, but that there was a great danger of the covers being taken off, or of the joints being improperly made, and there was the question whether enclosed motors were to be relied on. He (Mr. Davis) must state that enclosed motors, other than protecting the machine from mechanical injury, were a snare and delusion. The cubical contents of such cases were rarely considered, and in case of firing gas the case would undoubtedly be blown to pieces. It was impossible to make such cases air-tight, and more than impossible to keep them air-tight.

He might here call attention to a motor for colliery work which had been proved by considerable use to be a practical success, namely, the Davis and Stokes motor described by Mr. M. Deacon in the

*Transactions.** This motor had been thoroughly tested, both by Mr. Deacon and by Mr. Rhodes. It had been made to spark violently and fire gas inside the commutator, which was inverted and enclosed, but failed to communicate the flame to the surrounding gas. The cubical contents of the inverted commutator being reduced to a minimum, kept the explosion to a non-dangerous limit, and the flame-tight joints acted similarly to the gauze of a safety-lamp in cooling the flame so as to be innocuous. The motor, further, was so arranged that it could not be run unless it was properly closed, neither could it be opened while running.

Mr. RAVENSHAW wrote that he had had no practical experience with the Davis and Stokes enclosed commutator, and had not, therefore, expressed an opinion on it. There should be a good future for a perfectly safe arrangement in fiery mines.

A switch and resistance for breaking the shunt of a motor was a comparatively simple affair. To leave the shunt in circuit all day would waste a good deal of power, if the machine was standing for any length of time. If a series-wound motor was wound with 5 per cent. extra turns, a resistance to take about 5 per cent. of the current could be used without altering the speed. There was a great strain on the insulation if the circuit of a series-wound motor were broken when a resistance in parallel with the field was not used; a violent spark also occurred whenever the circuit was broken. With the shunted fields, however, the spark was very slight.

He preferred to have shunt-magnets wound with every layer of wire thoroughly insulated from the next. The potential on breaking the circuit was so great that there was a great tendency to break down from layer to layer. In compound-wound machines the series-coil should be entirely separate from the shunt-coil, a thick wooden washer intervening.

The heating and cooling of an enclosed motor caused a pumping action, which drew gas and dust through any defective joints. This did not occur with a switch, which could also be more easily made air-tight. The joints and stuffing-boxes were merely mechanical questions. He agreed, however, with Mr. Davis that in a switch there should be as little space as possible for gas.

He was glad to see that his views coincided so well with those of the members who had discussed his paper. He had looked at the disadvantages as well as the advantages of the concentric cable system, having no commercial interest in advocating any particular system or type of machine. The concentric cable was so great an improvement on the old system that it could afford to be criticized.

* *Trans. Fed. Inst.* vol. iii., page 192.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE INSTITUTION OF CIVIL ENGINEERS, 25, GREAT GEORGE STREET, WESTMINSTER, JUNE 5TH, 1896.

MR. G. A. MITCHELL, PRESIDENT, IN THE CHAIR.

Mr. BRYAN DONKIN read the following paper on "Powdered Coal for Firing Steam-boilers":—

POWDERED COAL FOR FIRING STEAM-BOILERS: WEGENER AND OTHER SYSTEMS.

BY BRYAN DONKIN, M.INST.C.E.

Preliminary.—The use of "powdered" coal should be carefully distinguished from the utilization of "dust" coal. The latter means $\frac{1}{16}$ to $\frac{1}{8}$ inch pieces, and can be efficiently burned on the Perret grate. With powdered coal the particles are about $\frac{1}{100}$ inch and less in size. It is generally admitted that the more intimate the mixture of fuel with the oxygen of the air, the more perfect the combustion, and the better the results from a chemical point of view. So that powdering the coal into very fine particles, instead of burning it in all sizes from $\frac{1}{16}$ inch to 2 inches in diameter, facilitates the chemical process called combustion, viz., the combination of the oxygen of the air with the carbon in the coal, and the formation of the maximum amount of carbon dioxide.

Former Powdered Coal Experiments.—The late Mr. Crampton was probably the first to take up the question of powdered fuel in England between the years 1868 and 1873. He made a large number of experiments with powdered coal for metallurgical purposes, a few with steam boilers, but always used forced-air supply from a fan. These experiments lasted five or six years, and Mr. Crampton invented a very ingenious apparatus for feeding the powdered coal into the boiler-furnace. The coal was ground to pass through a 80 holes sieve, and reduced to particles of about $\frac{1}{50}$ inch. His experiments, though costly and conducted with

great care, do not seem to have had much practical result. Mr. Crampton read an interesting paper before the Iron and Steel Institute in 1873, on "The Combustion of Powdered Fuel in Revolving Furnaces, and its Application to Heating and Puddling Purposes."* He estimated the cost of powdering the coal at from 6d. to 1s. per ton, according to the quantity ground, and seems to have made some experiments on a marine boiler with furnaces lined with firebrick. Some 2,000 tons of coal, it appears, were ground for his various experiments.

Combustion and Air-supply, etc.—For perfect combustion there should be a continuous and not an intermittent supply of fuel, and also exactly the right quantity of air for the particular coal consumed. The opening of fire-doors causes cold air to enter the boiler-flues, and diminishes the efficiency. Where possible, to prevent the entrance of too much air, there should be no grate, as it is always difficult to keep it regularly covered, either by hand or by mechanical stoking. With the proper quantity of air, high furnace-temperature, and automatic continuous supply of the finest particles of ground coal, the analyses of the gases prove that combustion is very perfect, and the percentage of carbon dioxide is much higher than is usual with ordinary sized coal. This result, in the Wegener system, is effected without forced or induced draught, and by simply using the chimney vacuum.

Analysis of Gases.—In all tests of steam boilers, the gases of combustion should be sampled continuously and then analysed, to ascertain the degree of imperfection of the combustion, and the percentage of oxygen, carbon monoxide, and carbon dioxide present. Any boiler experiment is imperfect without this. The temperature of the gases should also be taken at stated intervals. The writer uses an apparatus for taking samples of the gases, with which they can either be caught for two or three minutes, or a few cubic feet can be obtained continuously say for eight hours. By the latter method a better average sample is obtained.

Boiler Efficiency, Gases, Transmission of Heat, etc.—Steam-boiler results should not be compared simply in lbs. of water evaporated per lb. of coal, but by means of the much more correct standard of "boiler efficiency." In any boiler, whether using large pieces of coal ($\frac{1}{2}$ inch to 2 inches), or dust ($\frac{1}{16}$ to $\frac{1}{8}$ inch), or powdered coal ($\frac{1}{100}$ inch), the following points should be carefully attended to :—Quantity of air entering. Fire-doors opened for the minimum time. Grates well covered, and minimum leakage of air through the brickwork and cracks surrounding the boiler. Boilers should not be forced, and for the best results the

* *Proceedings*, vol. i., page 91.

evaporation should not exceed 5 lbs. of water per square foot of heating surface. More than this generally leads to waste, unless a large economizer is used. The boiler-plates should be kept clean, both outside and inside, as all dirt considerably diminishes the rapid transmission of heat from the gases to the water, so necessary for economical evaporation. The ordinary furnace-temperature may be taken at somewhere about 2,500 degs. Fahr. The gases should be allowed to escape from the boiler flues at a temperature only a little above that of the steam, so that the limits of temperature are 2,500 degs. Fahr., and, say, 400 degs. Fahr. Thus round the furnaces there would be a difference of temperature of some 2,100 degs. Fahr., which would cause heat to pass through the boiler-plates. This difference in transmission is gradually reduced as the gases pass to the end of the boiler, where it is very small. If an economizer be used, the temperature of the gases can be lowered considerably below that of the steam.

A series of twenty-one boiler experiments made by Messrs. Donkin & Kennedy, all fired with the same Nixon navigation coal, are summarized in *Engineering*,* where full particulars are given, with drawings, analyses of gases, boiler efficiency, heat balance, etc.

In several mills and factories on the Continent, the stokers receive a bonus in addition to their weekly wages, in proportion to the higher percentage of carbon dioxide in the gases—that is to say, the higher the percentage of carbon dioxide the greater their bonus. This is an excellent system, and in the right direction, and seems to work well both for masters and men. In the Appendix,† the author adds a note on the amount of oxygen, carbon monoxide, and carbon dioxide in various boiler experiments with large ordinary coal. These proportions, of course, vary much according to the local conditions, stoking, kind of fuel and grate used, boiler, leakage through brickwork, etc.

Boiler Efficiency.—Coal should be purchased not by weight, but by the quantity of heat it contains. There should also be a sliding-scale for the quantity of dirt and incombustible matter in it, that is, the greater the percentage of dirt, the lower the price. The quantity of dirt may easily vary from 5 to 15 per cent., so that the purchaser is paying for so much useless and harmful clinker, etc., which often costs him something to get rid of. On the Continent, in buying coal, the incombustible residuum, as also the heating value of the coal, are allowed for when fixing the price per ton. It is not tons of coal that is wanted by any boiler-owner, but so much heat, and he should look to getting a

* September 20th, 1895, vol. lx,, page 347. † Page 332.

maximum quantity of heat with a minimum quantity of dirt. The percentage of the total heat in the coal utilized in evaporating the water into steam is called "boiler efficiency." Thus the latter takes into account not only the dirt and clinker in the coal, but especially its heating-power. In all boiler experiments the heating value of the fuel should be given. So much heat is purchased in a ton of coal, and this evaporates so much water into steam at a given pressure. The feed-water should be measured, and the cost of evaporating 1,000 gallons of water per hour should be calculated.

Advantages and Disadvantages of Powdered Coal-firing as Compared with Large Coal.—Some of the advantages are :—Absence of smoke after the firebrick lining has become hot, continuous and automatic fuel-supply, less dependence upon the stoker, more perfect combustion, more easy regulation of the exact quantity of air required and of steam generated, saving in cost of labour, economy of coal, no grate or grate-bars, no fire doors, higher furnace-temperature, and increase of boiler-efficiency from 15 to 25 per cent. With boilers having an efficiency of about 55 per cent. the gain in efficiency will be greater than in those having 75 per cent.

Some of the disadvantages are :—The cost of grinding the coal, which will vary according to the locality and quantities ground, but may be taken at from 9d. to 1s. per ton. Repairs to the firebrick lining of Cornish and Lancashire boilers. In water-tube boilers no special brickwork is necessary.

Powdered Coal-firing: Various Systems.—There are five systems of powdered coal-firing now working in Germany, some with, and some without, forced blast, viz., the Wegener, the Schwartzkopff, the Friedeberg, the Ruhl, and the De Camp. A description of these various systems is added, with drawings, together with some experimental results lately published in Germany.

Practical Application of the Wegener System to Steam Boilers.—The author has only had personal experience with the Wegener system. There are now some 15 or more boilers in Germany which have been working regularly for the last year or two with the Wegener powdered coal firing, especially in Berlin, where attention is directed to producing the minimum quantity of smoke. Water-tube boilers are at work at the War Department, near Berlin; and Cornish and multitubular boilers elsewhere. At Messrs. Krupp's works there is a water-tube boiler, and a marine boiler at the Nord-Deutscher Lloyd at Bremen. An experiment on a Cornish boiler at Berlin by the author is added. One has been at

work in Paris on a Belleville water-tube boiler. Experiments at the Bermondsey works, on a Lancashire boiler with Wegener powdered coal firing, are still in progress, but not yet sufficiently complete for publication. In these trials the gases are analysed, the coal and feed-water measured, details studied, and boiler efficiency ascertained. The Wegener apparatus at Bermondsey works very well and easily, without smoke when once started, and has been seen by a large number of engineers. The stoking is regulated by a small thumbscrew, allowing more or less powdered coal to pass through the sieve into the furnace. Newcastle coal has chiefly been used; coke and Welsh coal seem more difficult to burn alone in a powdered condition, but could, no doubt, be burned in combination with bituminous coal, which burns very freely in powder. No difficulty is found with deposit in the flues. The lighting up is very easily and quickly effected. The firebrick lining is first warmed up with a little wood, the powdered coal then started, and ignited with wood or oiled rag. The heating-surface of the boiler at the Bermondsey works is 582 square feet.

Description of Wegener System of Using Powdered Coal (Figs. 1 and 2, Plate XVIII.).—The small sacks of powdered coal, weighing about ½ cwt., are put into a conical hopper. The powdered coal gradually falls out of the sacks, as required, into the hopper, and then on to a sieve about 5½ inches in diameter, with small openings in it. The powdered coal would not go through this sieve with certainty without continual tapping, and this is done in the following way:—Immediately beneath the hopper, and level with the boiler-house floor, is an air-pipe about 20 inches in diameter, through which nearly all the air for combustion is admitted. As it enters, it is made to pass through the blades of an air-wheel or turbine, and this passage of the air causes the latter to revolve. On the axis of this air-wheel is a little knocker, which taps the sieve from 150 to 250 times per minute, causing the powdered coal to descend vertically through the sieve, meeting the air for combustion as it ascends vertically. In this way the powdered coal and air for proper combustion get thoroughly mixed, and pass on into the boiler-flue, each particle of coal being surrounded by air. The stoking simply consists of putting the sacks of powdered coal, from time to time, into the top of the hopper, and seeing that the right amount of air is entering for combustion. If there be not sufficient air for proper combustion entering through the main opening, as seen by a little smoke, there are two other smaller pipes where additional air can be admitted, each kind of coal requiring a somewhat different amount. The only object

of the air-wheel revolving, from 50 to 80 revolutions per minute, is to shake the sieve and cause the powdered fuel to go into the furnace in the quantity desired. When more steam is required a greater knock is given to the sieve, and more powdered coal is burnt; when less is needed a less shake is necessary. An adjustment is provided to regulate the amount of coal entering, which is done by turning with two fingers the ½ inch screw. The duty of the attendant is to put the sacks of powdered coal into the hopper, and he ascends a short ladder to do this, or a conveyer can be used. One man can therefore attend to several boilers. The ignition of the powdered coal seems to take place immediately on its arrival in the hot firebrick chamber, and about 1 foot from the boiler front.

Wegener System Experiments.—Experiments with powdered coal on the Wegener system were made by Mr. C. Schneider at Berlin in 1892. He tested the first Wegener apparatus on a Cornish boiler with different kinds of coal, but the results were experimental only and have not been published. In 1895, he made various trials of the new Wegener system with a two-tiers boiler of the Lancashire type below, and having 72 tubes above, as shown in Fig. 3 (Plate XVIII.). The steam pressure was 7 atmospheres, and the total heating-surface 1,345 square feet. Five experiments were carried out with English coal, Bohemian lignite, and Upper Silesian hard coal. The heating value of the coal was carefully determined, and the boiler efficiency was 78 per cent. with Silesian coal, 79 per cent. with English coal, and 78 per cent. with lignite. Loss of heat to the chimney, 13½ to 15½ per cent. Loss by radiation, etc. (difference to balance account), 6 to 10 per cent. The quantity of water evaporated per square foot of heating surface per hour varied from 2·9 to 4 lbs. Analysis of the gases of combustion showed that the percentage of carbon dioxide at the end of the boiler was from 11 to 14 per cent. The temperature of the gases varied very slightly. Observations were made of the degree of smoke, and diagrams were taken, but the data were not available at the time of publishing the experiments. The quantity of smoke was practically *nil.*

Experiments on a Cornish Boiler with Powdered Coal, Wegener System, at Berlin, by the Author, 1895.—Two experiments were made on the same boiler, with the same steam pressure, and the same coal. One with rather small coal, about ⅛ inch pieces, hand-fired, and the other with the same coal, powdered in the usual way, 0·01 inch pieces. The total heating-surface was 500 square feet. The feed-water was measured in a tank. The duration of the trials was about seven hours. The general

results of these two trials may be summarized as follows:—The calorific value of the coal was practically the same in both cases. The thermal efficiency of the boiler was 54 per cent. with ordinary coal, and 77 per cent. with powdered coal. Making an allowance for the coal being rather too small for the fire-bars in the first case, we may take the efficiency of this trial as 58 per cent. The temperature of the furnace-gases was very nearly the same in both cases, and they were analysed every quarter of an hour. With regard to the percentage of carbon dioxide in the gases, in the first case it was $8\frac{3}{4}$, and with powdered coal $15\frac{1}{3}$ per cent.; the percentage of oxygen was respectively 8 and 3 per cent., and that of carbon monoxide 0·9 per cent. and *nil*, showing much better combustion with the powdered coal. The chimney was constantly watched by a competent observer, and notes made of the degree of smoke every minute or two. The total visible duration of smoke in the first case was $1\frac{3}{4}$ hours of No. 7 on the smoke scale, and with the powdered coal 6 minutes of No. 5 scale.* This shows that with powdered coal in this experiment there was practically no smoke.

Schwartzkopff System of Powdered Coal-firing (Figs. 4, 5, and 6, Plate XVIII.).—In this apparatus a circular brush, rotating rapidly, is used to introduce the powdered coal into the boiler-furnace. The coal first passes into a hopper, which contains in its lower part near the brush a metal plate, and a valve held against it by a spring. A cam on the brush strikes at each revolution against the valve, and forces it from the plate. The powdered coal falls through on to the brush, and is thrown by the rapidly revolving bristles into the boiler-furnace. As the valve is released and springs back against the plate, a shake is given to the hopper, which facilitates the descent of the powdered coal. The furnace is lined in the usual way, and has a fire-bridge. The brick walls soon acquire a temperature high enough to kindle the powdered coal as it enters. The object of lining a furnace with firebrick is that sufficient heat may be absorbed to ignite the powdered coal readily, and this also helps to consume the smoke. Air is introduced from above into the brush, and below it into the furnace, and the admission in both places is regulated by dampers. The quantity of powdered coal is determined by adjusting the screw against the plate, to enlarge or diminish the opening between the plate and valve,

* No. 10 means "black smoke," No. 0 means *nil*, and nine numbers intervene between.

and the position of the cam. The apparatus is made in two sizes, the smaller with a brush about 8 inches in diameter suffices for 250 lbs. of coal per hour; the larger is double the above dimensions, and deals with twice as much coal. Fig. 6 is a view of the apparatus, and Figs. 4 and 5 of the boiler upon which the following experiments were carried out.

Experiments at Berlin in 1894 *on a Two-flued Boiler with Schwartzkopff Powdered Coal-firing.*—The total heating-surface was 150 square feet. Two kinds of coal were used in these tests, hard German coal and lignite, and three complete trials were made. The boiler-efficiency varied from 59 to 60 per cent.; chimney losses 18½ to 22 per cent.; loss of heat by radiation (difference to balance) 18½ to 22 per cent. These experiments seem to have been very carefully made, but it will be noticed that the boiler-efficiency is much lower than with the Wegener system. The gases were analysed, and the carbon dioxide was found to be 15½ to 18 per cent. at the end of the first flue, and 14 to 16 per cent. at the end of the boiler; although the chimney was carefully watched there was practically no smoke.

Another series of four experiments were made by Mr. Schneider at Berlin in 1895, in connexion with the Smoke Abatement Commission. The trials were on a Lancashire boiler having a total heating-surface of 591 square feet, and working at 7 atmospheres of steam pressure. The coal used was hard Silesian and Westphalian, powdered. The boiler-efficiency varied from 72 to 79 per cent. Heat lost up chimney 10 to 15 per cent., lost by radiation (difference) 10 to 18 per cent. Percentage of carbon dioxide 16½ to 18 per cent. at end of first flue, 14 to 15½ per cent. at end of boiler. No smoke.

Friedeberg System of Powdered Coal-firing (Figs. 7 and 8, Plate XVIII.). —In the Friedeberg system, a blast of air is blown by a fan through the coal-dust, with which it mixes, carrying it forward into the boiler-furnace. The air is introduced through a pipe and divided into two currents. The upper passes through two nozzles into a chamber below the hopper, where it meets and carries off the powdered coal from above. On entering, the air-blast strikes against the lower edge of the column of powdered coal from the hopper, and sweeps it along, and as it is instantly replaced, a continuous supply is thus secured. The second current of air is introduced into the boiler-furnace through the lower pipe, and the two streams mix in an annular conical opening, as

shown in the drawings. The quantities of powdered coal and of air are regulated by throttle-valves. There are no moving parts except the fan, and one fan will supply several boilers.

Experiments with the Friedeberg system of powdered coal-firing were made on the same boiler as was used in the Schwartzkopff trials, described previously. They were carried out in Berlin in 1895 by Mr. Schneider acting for the Smoke Abatement Commission. Four experiments were made with the same coal, and the trials were in every respect similar. The water evaporated per square foot of heating-surface per hour varied from 3·5 lbs. to 4·7 lbs. The boiler-efficiency varied from 66 to 77 per cent. The loss of heat up the chimney varied from $11\frac{3}{4}$ to $12\frac{3}{4}$ per cent. The losses by radiation and difference (balance) 20 per cent. The percentage of carbon dioxide at the end of the first flue was 16 to 17 per cent.; at the end of the boiler, it was $14\frac{1}{2}$ to 16 per cent. No smoke was observed.

Ruhl System of Powdered Coal-firing (Figs. 9 and 10, Plate XVIII.).—To introduce the powdered coal, Mr. Ruhl uses a worm provided with two brushes, working in a closed groove; the brushes catch up the coal through a slit in the bottom of the groove, and sweep it into a vertical pipe below. Here it is carried to the front of the furnace, falls into the current of air produced by the chimney-draught, and is introduced as a mixture of powdered coal and air. The boiler-flue is lined as usual with firebrick, and there are firebrick-baffles, as shown in the drawings. The size of the groove, which regulates the quantity of powdered coal admitted, is adjusted by a screw, and the section of the air-orifice is also determined by a damper. There is a second worm parallel to the first, which automatically carries back the powdered coal which has not passed the slit. The same mechanism will supply several furnaces. This apparatus is simple, and has the advantages of requiring no fan, and little power to drive the screw. Comparative experiments on different lines from those already described were made in 1895 with the Ruhl apparatus. Two Lancashire boilers were used, one fitted with a plain grate, the other with the Ruhl powdered coal-firing. Ordinary German lump coal was used in the experiments with the plain grate, and English coal with the powdered coal-system. Comparing the two systems, the boiler gave an efficiency of about 17 per cent. more with the Ruhl apparatus than when fired with large coal in the usual way. The steam-pressure was $2\frac{1}{2}$ atmospheres.

De Camp System of Powdered Coal-firing (Fig. 11, Plate XVIII.).—This inventor uses a fan to blow a mixture of air and powdered coal, and not, as usual, a blast of air only, into the boiler-furnace. A hopper is placed over a screw and the latter delivers the powdered coal from the hopper into a chamber surrounding a cylindrical sieve, through which air passes to the fan and mixes with the powdered coal on its way. By this arrangement all the coal passes through the fan. The cylindrical sieve and screw are set in motion by wheels and pulleys from the fan, as shown in the drawing, and the speed of the latter can be varied. One advantage claimed for the De Camp arrangement is that the same fan can supply several furnaces, because it delivers a mixture ready for combustion. The system has been working for some time with a boiler in Germany, and is said to give good results, but no experiments appear to have been made upon it.

Summary.—We thus have, say up to the end of 1895, five different systems of introducing powdered coal into a boiler-furnace. Three of these, viz., the Wegener, the Schwartzkopff, and the Ruhl do not use any fan, and two, viz., the Friedeberg and the De Camp, employ a fan. In the last, both the air and the powdered coal go through the fan, a circumstance which will, no doubt, add to its internal wear. In the case of the revolving brush of the Schwartzkopff furnace, the power although small, and the wear of the brushes should be considered. Something must be allowed for the power to drive the fan, and the small cost of maintenance. The cost of coal-grinding must in all cases be taken into account. Where a fan is used, the particles of powdered coal may probably be a little larger and heavier than where no fan is used, but this will depend upon the amount of the blast, the disposition of the air-pipes leading to the furnace, and the speed of the air. With an arrangement without a fan, as the particles of coal, put in motion by the chimney vacuum, float in the air, they must, of course, be very light, and the pipes should be arranged with as few changes of direction as possible, to conduct the air loaded with the finely powdered particles to the furnace.

Mr. M. Longridge, of Manchester, has for many years published accounts of excellent boiler experiments in his *Annual Reports*, with complete heat balance-sheets and efficiency of many steam boilers, with ordinary sized coal. He nearly always records the analyses of the gases of combustion.

Powdered Coal under the Microscope.—When powdered coal has passed through a 60 holes woven wire-gauze with spaces about $\frac{1}{100}$ inch square, it is of interest to know the dimensions of the particles and their shape. The writer has measured these particles under a microscope, and appends a copy of a photograph (Fig. 12). The largest particles are

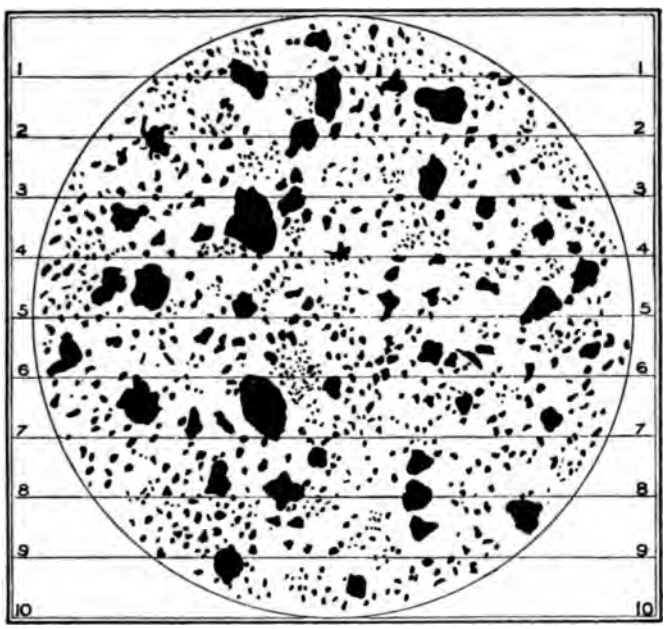


Fig. 12.—Powdered coal, copied from a photograph magnified to 60 diameters; the lines are $\frac{1}{10}$th inch apart. The original size of the enlarged disc was ●

$\frac{1}{100}$ inch, and the smallest (or nearly so) $\frac{1}{5000}$ inch, taking the longest measurement, with all sizes between these. They are generally oblong in shape, and none seem circular. Considering the high speed of the disintegrator or grinding mill, this is what might be expected.

Loss due to dirty Boiler-plates.—With a Cornish boiler the effect of dirty boiler-plates, after one month's work only, has been well brought out lately by an experiment made by Mr. Stagg on a Cornish boiler at a gas-works. The water used had been filtered, and not very hard. With clean plates, the evaporation was 9·06 lbs. of water per pound of gas coke; after four weeks' work, fired with the same coke, only 8·15 lbs., a diminution of 0·91 lbs., or about 10·4 per cent. less evaporation, or $10\frac{1}{2}$ per cent. less heat transmission due to dirt on each side of the boiler-plates. This experiment shows the importance of removing all soot and

dust from the outside, and any scale from the inside of the boiler plates, more often than is generally done. The above loss would have been greater still after a longer time without cleaning.

Variations of efficiency due to Hand-stoking.—In some experiments lately made by Mr. Radford, of Sheffield, for the Smoke Abatement Society in that city, stoking made an increase of from 7·4 to 9 lbs. of water per square foot of heating surface per hour, or 22 per cent. difference. This increase, with five different stokers, is due to the different methods of stoking, each trying to diminish smoke to the utmost and to increase the evaporation. The boiler and coal used were the same in all the experiments. The above results calculated for boiler-efficiency would make a difference of 11 per cent. gain due to better stoking and management of fire and draught, etc.

APPENDIX.

ANALYSIS OF FURNACE-GASES FROM VARIOUS TYPES OF STEAM BOILERS USING LARGE COAL.

Type of Boiler.	Percentages of Carbon Dioxide.	Percentages of Oxygen.	Percentages of Carbon Monoxide.	Percentages of Boiler Efficiency.
Lancashire, two flues, varying from ...	14 to 6	4 to 14	0·1 to 0·4	70 to 55
,, three flues, ,, ...	13 ,, 9	7 ,, 11	0·1 ,, 0·4	—
Cornish, one flue, ,, ...	15 ,, 8	6 ,, 13	0·3 ,, 0·4	78 ,, 62
Marine	9	10	—	71
Locomotive, varying from	16 ,, 7	3 ,, 16	0·0 ,, 1·0	80 ,, 57
Water-tube, ,, ...	11 ,, 6	5 ,, 12	0·1 ,, 1·0	74 ,, 62

Mr. A. L. STEAVENSON (Durham) said that both Mr. Donkin and himself had both been at work on this subject, though on somewhat different lines. Mr. Donkin was endeavouring to make the best of that which was already good in the shape of the best quality of coal, while he was endeavouring to make the best of that which was bad. Most of the members present were connected with coal production, and unfortunately they produced a considerable quantity of material which they could not use, particularly was this the case at collieries producing coke for use in blast-furnaces, as they took only the best fuel, while the small coke and ballast was thrown on to the waste-heap. To utilize this material he had been trying two or three different kinds of furnaces, and he had succeeded in satisfying himself, and hoped to bring the matter before the Institution at an early date.

SCHWARTZKOPFF SYSTEM.

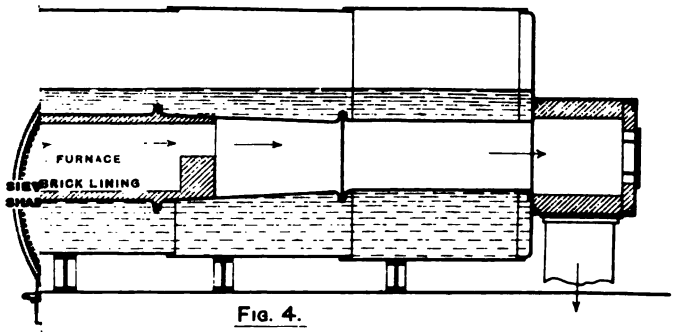


FIG. 4.

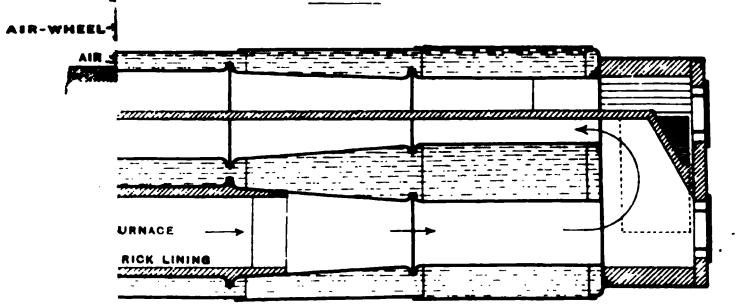
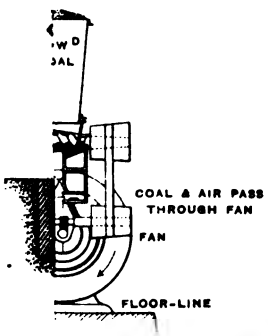


FIG. 5.



FRIEDEBERG SYSTEM.

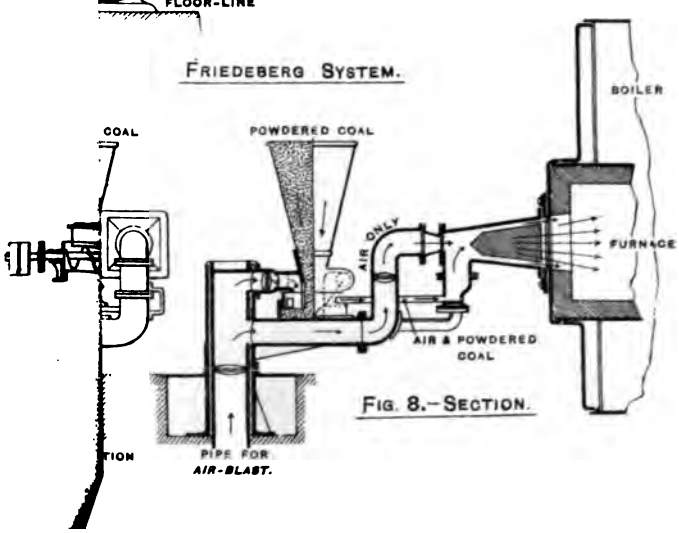


FIG. 8.—SECTION.

He would first mention that coal crushed so fine became "winded" if it were exposed to the atmosphere for any length of time, and thereby became inferior. In dust firing it is dangerous to keep more than two or three days' stock of coal-dust in hand, or it might be ignited by spontaneous combustion. Mr. Donkin apparently used it as soon as it was crushed—this was quite right, and precluded these sources of danger. As many of the members had not seen the dust-coal referred to by Mr. Donkin, when visiting the boiler at the Bermondsey works, he had taken a small sample of it for their inspection: it appeared to be as fine as the impalpable dust which was found on the timbering in mines, and which during late years had proved so great a source of danger. He hoped that Mr. Donkin would try the dust a little more roughly ground; at present he (Mr. Steavenson) thought that the crushing was carried to an extreme. While referring to crushed coal, he might also refer to the cross-tubes used in Lancashire boilers; unless the coal was crushed to that fine state cross-tubes did more harm than good, as they prevented the complete combustion of the furnace gases, but with dust-coal the combustion is instantaneous. The percentage of carbon dioxide was high, and this was no doubt natural. If Mr. Donkin had got fairly good results when using large coal it naturally followed that if he did not get good results in all cases, it was not the fault of the size of the coal, but owing to the way in which it was used. Mr. Donkin referred to the results which he had recorded in *Engineering*,* and in some of those results were even higher percentages than those mentioned in his paper, in one case 16·50 per cent., he presumed with large coal. He judged that, if it were possible to get fairly good results when using large coal, there was no particular reason why, if they did not get it always, it should be attributed to the want of dust. The maximum of carbon dioxide would be from 19 to 20 per cent. when using one and a half times the volume of air, as they were bound to use a larger volume than was theoretically necessary in order to burn all the carbon. Of course in this case they might run it to a finer point, and probably use less than one and a half times that weight of air, and still obtain very perfect combustion. The efficiency of boilers was no doubt the unassailable point, but one should not forget the quantity of water boiled in a given time or duty. The temperatures of boiler chimney gases varied, and they should arrive at what was the best heat to aim at. He believed that Mr. Donkin used about 300 degs. Fahr., or very little above boiling-point, and with that temperature he thought that the boilers would do little work. He had tested some boilers a few

* September 20th, 1895, page 347.

months ago, and at 400 degs. Fahr. they were doing little more than half the work that they would do if slightly pushed. He calculated some time ago that supposing he had five boilers, and the final temperature of the gases was 800 degs. Fahr., it would pay him to put down another Lancashire boiler, and work at 500 degs. Fahr. It was better to work at 500 degs. with six boilers, than at 800 degs. Fahr. with five, and the cost of the extra boiler would be recouped in about two years. If a Lancashire boiler 8 feet in diameter be pushed it would evaporate 70 to 80 tons of water in twenty-four hours, this was a high result, and more than ought to be obtained in ordinary working. From 30 to 40 tons were usual results, but these were all very low duties, of course there was a good efficiency —78 per cent.

The ordinary furnace temperature was said by Mr. Donkin to be about 2,500 degs. Fahr., but he (Mr. Steavenson) thought that it would often be a good deal more. Mr. Donkin did not say what temperature he observed when using dust; probably it was very high. Mr. Donkin also stated that coal of the highest class should be purchased, so as to ensure a high efficiency. It was common to find 15 per cent. of ash amongst coal, but the price accommodated itself to the quality, and users might consider whether it was better to pay 8s. 6d. for poor coal or 11s. for that of a higher class.

With powdered coal-firing, smoke was instantly prevented by immediate combustion. There could be no question at works situated in towns, where they were bound by strict laws to prevent smoke, that powdered coal-firing would obviate it much better than any other system.

At Bermondsey, the coal-dust was put up in bags, but he was inclined to think that it might be advisable to blow in the dust-coal from the disintegrator at the rate required for combustion, and thus do away with the labour of carrying the bags to the hopper. Labour was an important item, but, on the other hand, crushing would cost from 9d. to 1s. per ton. He had found that hand-firing for a consumption of 800 tons of fuel a month cost 11·60d. per ton: they were only working 8 out of 24 hours, so that it was not such a fair test as working continuously. It was, however, clear that crushing of coal did not cost more than the present hand labour of firing. He would like Mr. Donkin to try the effect of forcing the boilers a little to show the effect and the difference, more or less, in the quantity of water evaporated in 24 hours. In noticing the experiments made at Berlin, Mr. Donkin said that large coal gave an efficiency of 58 per cent., and

dust-coal 77 per cent. If members referred to Prof. Thurston's work on engine-boiler trials, they would find that experiments were given reaching 73 per cent.; and if it was possible at that time to obtain an efficiency of 73 per cent. with no doubt large coal, it did not follow that the difference between 58 and 77 per cent. was to be entirely placed to the credit of the dust-coal firing. Mr. Donkin even gave higher percentages himself, in the Appendix to his paper, for large coal-firing.

In the case of collieries, ample boiler-power might be originally provided, but in course of time as the workings became extensive and distant from the shaft, more water was pumped, and the work increased from time to time without a corresponding increase of boiler-power, hence they had often to force the boilers. Mr. Donkin was working for the benefit of mankind, and he had much pleasure in moving a very cordial vote of thanks to him for his valuable paper.

Mr. E. B. WAIN (Stoke-upon-Trent) remarked that if Mr. Donkin and Mr. Steavenson found out any means by which the quantity of coal consumed might be reduced it was probable they would be looked upon as national benefactors, the same as the man who could make two blades of grass grow where only one had grown before. He (Mr. Wain) thought that a Lancashire boiler such as Mr. Donkin described, with 582 feet of heating-surface evaporating 5 lbs. of water per square foot, would yield about 100 horse-power when applied to the best type of modern engine, using about 30 lbs. of steam per indicated horse-power per hour; but if they adopted such calculations, the ranges of boilers at mines would assume enormous dimensions. Mr. Steavenson mentioned that he got out of an 8 feet by 30 feet Lancashire boiler something like 300 to 330 horse-power. With the Lancashire boiler it was questionable whether it was advisable to reduce the terminal temperature too low in the boiler; whether there were not considerations of expansion and contraction in the boiler that might be injurious; and whether it was not better to get extra efficiency by means of some system of economizer rather than reduce the terminal temperature in the boiler.

The advantages and disadvantages of powdered coal-firing raised the question as to the loss of heat from the firebrick lining, and whether some system of baffle-plate similar to the Bunsen burner would not be advantageous. He had the opportunity of seeing the Wegener apparatus at work at Bermondsey, and it was very striking to see the condition which the slag assumed. It must have experienced the most intense heat before being reduced to the state of something like furnace-slag.

The combustion seemed to be perfect; there was no trace of cinder or coke; he wondered how the slag was deposited, and whether the deposit was of such a nature as to coat the firebrick lining to such a thickness as to form a non-conducting medium between the fire and the plates. The cost of fuel was said to be increased by 1s. a ton for grinding, and the efficiency of the fuel increased by 25 per cent. Mr. Steavenson said that the cost of hand-firing was about 11d. a ton, but with dust-firing there was more or less labour, and it was not fair to place 1s. per ton for grinding against 11d. per ton for hand-firing. In colliery districts, where inferior fuel could be obtained for something like a quarter of its cost in London, the addition of 1s. per ton would practically destroy the value of the apparatus as rendering the boilers more economical as regards cost of fuel. Another question that might be of some interest would be as to what pressure of chimney draught was necessary with the Wegener system; and still another, which bore more particularly on the great coal-dust question (not the firing with coal-dust, but the danger of coal-dust in mines), it would be interesting to know what weight of coal-dust per cubic foot of air gave the most perfect combustion. He had pleasure in seconding the vote of thanks; no one was more qualified than Mr. Donkin to deal with the subject, and he had given them a specially interesting paper.

The PRESIDENT said that Mr. Donkin might tell them something about the quantity of ash in the dust fuel. If it were possible to use small coal containing something like 20 to 25 per cent. of ash in the Wegener apparatus, the small coal which they could get naturally and without any crushing might be used. Colliery owners had difficulty in utilizing the dust from the washing-machines, and if that could be used with advantage, considerable saving would ensue.

Mr. DONKIN, in reply to the last question, said that his experiments had not lasted sufficiently long to determine the maximum quantity of ash which might be burned with powdered coal. The only similar fuel that they had tried was gas-coke, and that did not ignite easily, and required to be mixed with a certain amount of bituminous coal. Gas-coke often contained 15 to 30 per cent. of dirt and yet they burned it, —not in powder, but in the ordinary system with forced blast. To burn all kinds of low class fuels economically was very advantageous.

In speaking of large coal, small coal, dust-coal, and powdered coal, it seemed to be extremely necessary, to avoid confusion, to define clearly the size of the pieces. The dust-coal was finely ground, and, as used

at Berlin, was passed through a 60 holes sieve, which was found to answer very well. No doubt long exposure of the coal to the atmosphere might diminish its calorific value, but they were obliged to use it fairly dry so that the question did not arise in practice, as powdered coal containing 10 to 15 per cent. of moisture would not burn; with 2 or 3 per cent. it burned fairly well. He had never heard of spontaneous ignition of powdered coal after it had been kept. At Berlin, the coal had been stored for months—perhaps years— and always burnt easily.

With powdered coal, the question of the size of the particles would require a lengthy series of experiments, and the results would be very valuable. The greater the draught, larger particles could be used—their weight would be greater. The particles must be kept suspended in moving air, and the greater the fan-blast or the speed of air the heavier would be the particles. At Bermondsey, the chimney-draught was 0·30 to 0·40 inch of water, and the powdered coal was drawn into the furnace by the vacuum in the chimney.

He agreed with Mr. Steavenson on the question of the uselessness of cross-tubes. He did not like them, though not for the reason Mr. Steavenson gave. Cross-tubes were not necessary for strengthening the flues, nor for circulation of water, but the great reason against their use was that the flues could not be cleaned. He was now speaking of the use of large coal, but the same objection applied when using small and dust-coal—the flues could not be easily cleaned, and the heating-surface was considerably diminished. After proper cleaning, the evaporation was always increased.

Generally with powdered coal-firing, the percentage of carbon dioxide was decidedly higher; but to make any exact comparison of the two systems, the same conditions and arrangements were necessary. Of course, in the very best boiler experiments a high percentage of carbon dioxide would be found; but all things being equal, his experience was that powdered coal gave a higher percentage than large coal.

The question of forcing a boiler was an important one, and very properly raised in the discussion. A larger quantity of water could be evaporated, but could it be done economically? Had they estimated the cost? Something would be gained by the use of an economizer, but that was another appliance, and it had its own efficiency. To secure the best boiler efficiency the temperature of the gases should be slightly above that of the steam, if higher, it should be reduced by an economizer.

He had not been able to measure the temperature in the furnace, and he did not know of an instrument suitable for this purpose. Melting

iron or steel gave only approximate results. Some experiments for registering the high temperature of boiler-flues were being made with an electrical thermometer. He did not know whether it could be used for the furnace itself: at any rate he had not taken the temperature with this apparatus.

There was no doubt that boiler efficiencies varied enormously. He (Mr. Donkin) had summarized in *Engineering** twenty-one boiler experiments and their efficiencies. This efficiency was heat utilized of the total heat in the fuel. With large coal it rose to about 75 per cent., or even higher, but the more general result was 50 to 60 per cent., and the gain with powdered coal would be greater with inefficient than with highly efficient boilers. Mr. Wain said that a Lancashire boiler, 8 feet in diameter and 30 feet long, yielded 330 horse-power. But what was the efficiency of the boiler while doing it—did they get an economical evaporation?

With regard to the slag, as there was no grate with the powdered fuel, the slag fell to the bottom of the circular flue and solidified there, so that it was difficult to get it out and weigh it. It was heavy slag, and no doubt it would be possible to tap it and draw it out in a liquid state.

He (Mr. Donkin) had not tried any of the fine dust, found on the timbering of mines, but he would be glad to try it if supplied to him; to burn satisfactorily, it should be small enough to pass through a 60 holes sieve. As to the question of the number of cubic feet of air per lb. of powdered coal which would give the best combustion, it would only be necessary to have an analysis of the coal and it could then be calculated.

The PRESIDENT said that the members were indebted to Mr. Donkin not only for his interesting paper, but for his kindness in allowing the members to inspect the appliance.

The vote of thanks was carried with acclamation.

Mr. G. E. COKE read the following paper on the "Southern Limit of the Nottinghamshire Coal-field":—

* September 20th, 1895, page 347.

SOUTHERN LIMIT OF THE NOTTINGHAMSHIRE COAL-FIELD.

By G. E. COKE.

The Coal-measures to the south of Nottingham are hidden beneath a considerable thickness of Trias and later formations, due, to some extent, to a large downthrow fault. Consequently, there has been considerable uncertainty as to how far the coal-field extends in a southerly direction.

The most important explorations below the Red Measures to the south of the town of Nottingham have been made at the following points (Figs. 1 and 2, Plate XIX.):—*A*, Clifton colliery; *B*, Brickyard Spinney borehole; *C*, Owthorpe borehole; *D*, Edwalton borehole; and, *E*, Ruddington borehole. Reference will also be made to *F*, Bestwood colliery; *G*, Highfield borehole; and, *H*, Stanton Gate trial shaft.

Clifton is the most southerly colliery in the Nottinghamshire coal-field; it is situated in the borough of Nottingham, nearly 6 miles to the south of Bestwood colliery. There are other collieries intervening between Clifton and Bestwood, but the presence of faults, and other immaterial considerations, make it advisable to discard them in favour of Bestwood for the purpose of the question discussed in this paper.

At Bestwood colliery, *F*, the sinking commenced in the Lower Bunter, and after penetrating 120 feet of Permian strata, Coal-measures were reached at or about a height of 1,024 feet above the top hard coal-seam. At Clifton colliery, *A*, the Permian formation is entirely absent, and the Bunter lies on the surface of the Coal-measures, which here is only 37 feet above the top hard coal-seam.

The Spinney borehole, *B*, was one of three experimental borings made (previous to the sinking of Clifton colliery) on the Clifton estate, and it was thought that the top hard coal-seam had been proved, with about the same amount of overlying Coal-measures as was subsequently found in the Clifton shafts. The writer is satisfied that this borehole, so far as the Coal-measures are concerned, is misleading, and has discarded the information which it was believed to convey.

The Owthorpe borehole, *C*, was commenced, the writer believes, in 1876, under the direction of the late Mr. J. T. Woodhouse, and with the

flat-rope system. It was subsequently completed in 1884 by the diamond drill. The writer does not consider the upper and most important part of this section in the Coal-measures to be very trustworthy, but, so far as he is able to form an opinion, it should be correlated with that of Clifton colliery.

The writer has little doubt as to the Edwalton borehole, *D*, though he believes there are competent authorities who differ from him. He considers that the Coal-measures were struck just above the dunsil coal-seam.

The Highfield borehole, *G*, after penetrating 258 feet of drift and Bunter, reached Coal-measures at or about 208 feet below the top hard coal-seam.

The information from these various experiments pointed to this result, namely, that the Coal-measures had been subjected to considerable denudation between Bestwood and Clifton collieries; but to the south of Clifton this had to some extent ceased, and it seemed that the Coal-measures were always struck at or about the horizon of the top hard coal-seam whenever the overlying Red Measures were penetrated; consequently, it was hoped, that productive Coal-measures would be found to extend a considerable distance to the south of Nottingham. Eventually it was decided to make the experiment at Ruddington in order to decide if any workable coal-seams extended under the estate of the Paget trustees.

The Ruddington borehole, *E*, was consequently commenced, in June, 1895, by the Vivian Diamond Boring Company, and after penetrating 466 feet of Keuper and 218 feet of Bunter the Coal-measures were reached towards the end of September, at a depth of 684 feet from the surface. Early in November a seam of coal was proved, and it was found possible, by comparison with other local sections, to obtain some idea of its horizon. The section agreed with one only, and that was a trial below the Kilburn coal-seam, made by the late Mr. North, near Stanton Gate station, *H*. Mr. Shipman (probably the best authority on local geology) agreed with this view, and suggested to the writer that the southern limit of the coal-field can now be known with considerable probability of accuracy.

The plan (Fig. 1, Plate XIX.) shows the limit of the top hard coal-seam on these assumptions as far as Owthorpe, and the limit of the Kilburn coal-seam to Ruddington. The section (Fig. 2) brings out clearly that the surface of the Coal-measures dips towards the south, from Bestwood to Ruddington, while the coal-seams rise considerably in this direction. The joint result is a wedging out of the Coal-measures to the south, and this accounts for the startling rapidity with which they dis-

appear. The Ruddington borehole, *E*, is within 2½ miles of the Clifton workings, in the deep hard coal-seam, and the depth from the surface is probably not very different from the depth at which the Naughton coal-seam is found at Ruddington. Yet the Naughton coal-seam is over 1,100 feet below the deep hard coal-seam, so that the Coal-measures must rise at an average gradient of 500 feet to the mile between these points.

The writer takes this opportunity of thanking the Paget family for their generosity in allowing the results of the Ruddington boring to be utilized for the advancement of the geological and mining knowledge of the district.

Mr. J. J. H. Teall (H.M. Geological Survey) said that the district had been mapped many years ago on the 1 mile to 1 inch scale, and no member of the existing staff of the Survey had assisted in the work. The northern part of the Nottinghamshire and Yorkshire coal-fields had been mapped at a more recent date, on the 6 inches to the mile scale, and the information was therefore of a much more detailed character.

He would be sorry to let this occasion pass without expressing his opinion as to the importance of Mr. Coke's paper, so far as the precise limitation of the southern part of the coal-field was concerned. The *Report* of the Coal Commission of 1871 contained a map indicating the supposed general distribution of the Coal-measures beneath the newer rocks in that district, and Mr. Coke's conclusions, assuming them to be correct, certainly seemed to indicate that the Coal Commission under-estimated, rather than over-estimated, the extension of the coal-field. This map placed the southern limit very close to Clifton colliery—only a short distance to the south. Mr. Coke's paper pointed to the important conclusion that the Coal-measures were still striking towards the south-east—even as far east as Owthorpe.

This communication afforded a striking illustration of the importance of a series of borings for determining the distribution of the underlying strata. By means of such a series, Mr. Coke had been able to draw the approximate outcrops of two important coal-seams beneath the uncomformably overlying red rocks. It was much to be regretted that the precise details of all the borings discussed in the paper were not available, particularly of the boring at Owthorpe. The paper also illustrated the desirability of having access not only to records of old borings, but also to actual specimens obtained from the boreholes. The space at the Jermyn Street museum was limited, but he had the authority of the

Director-General for saying that the Geological Survey would be glad to render any assistance in its power in storing cores obtained from important borings for future reference. It might perhaps be more convenient to have them stored locally, but it was of the utmost importance that they should be stored, whenever possible, in some public institution. Subsequent information often enabled geologists to interpret stored specimens which appeared to be useless at the time they were obtained.

He imagined that important developments of this great coal-field, which was second only to that of South Wales, would take place in the near future. Small faults in the overlying rocks often corresponded to important faults in the underlying Coal-measures, and in the north of France slight rolls corresponded in the most extraordinary manner with important anticlines and synclines, so that there was every reason to believe that a detailed survey of the overlying rocks would throw important light on the structure and distribution of the concealed portion of the coal-field. In view of future developments, he would very much like to see the results of a careful re-survey of the overlying Triassic rocks. The paper was an important one, because it gave precise information on points on which they had before only vague suppositions.

Mr. M. H. Mills said there might have been more said in Mr. Coke's paper about water. In the Nottingham district it was nearly of as much importance as coal. Personally, he did not agree with the southern boundary as drawn by Mr. Coke in Fig. 1 (Plate XIX.). It might be the southern boundary of an anticlinal, and there was every possibility that it was only an anticlinal, and that there might be a synclinal giving another coal-basin further to the south.

Mr. C. E. de Rance (H.M. Geological Survey) said that he had read Mr. Coke's paper with much interest, as the facts adduced fix the eastern position of the boundary of attenuation of the Zechstein Permians, and moreover point to their absolute absence southward of Nottingham, as he had endeavoured, in a recent paper, to prove is similarly the case in Central Cheshire and North Staffordshire. Prof. Hull, in a footnote to the fourth edition of his *Coal-fields of Great Britain*,* had already pointed out that—

> On approaching the valley of the Trent, the Permian beds become attenuated and debased, the Magnesian Limestone passes into a yellow Calcareous Sandstone, and the Lower Sandstone is but feebly, if at all, represented. All this in consequence of the near approach of the formation to its original margin, formed by the uprising of the Lower Carboniferous and still older rocks of Charnwood forest above the sea-level of the period.

* Page 245.

At Shireoaks colliery, the Permian rocks are 196 feet; at Bestwood, where they are overlain by the Bunter, only 120 feet thick; at Clifton they have disappeared altogether. From the map and section accompanying Mr. Coke's paper, he (Mr. de Rance) had plotted the accompanying longitudinal section (Fig. 3, Plate XIX.), adopting the scales there used, which clearly showed that the tilting of the Coal-measures took place before the Permians were deposited; that both formations were extensively denuded before the Triassic rocks were deposited; and that this denudation increased southwards at a very rapid rate, and so that the surface of the Coal-measures dips rapidly south, or in an opposite direction to the dip of the measures themselves, the intervening vertical space being filled in with Triassic rocks of an increased thickness. It would appear probable that this disposition of comparative levels is entirely due to a series of faults throwing down the strata southwards, and it is clearly established that these faults are of newer date than the Triassic formation, and, consequently, Prof. Hull is probably correct as to the Permians thinning out against the uprise of old Palæozoic rocks.

Mr. J. Bagnold Smith (Newstead) wrote that Mr. Coke's information and deductions seem to be very correct and of great interest. If the approximate line of outcrop be correct, it gives a knowledge of it from north of Eckington of the Brimington anticlinal to south of Nottingham. When read in conjunction with Prof. Rücker and Thorpe's Bakerian lecture of 1890 it presents features of great interest in connexion with the magnetic ridge-lines, which show folds in the primary igneous rocks, and these folds are nearly related to the contour of various coal-basins and the lie of the stratified rocks (Fig. 4, Plate XIX.). In a magnetic survey of Belgium, made, he believed, in 1869, by the Rev. S. J. Perry and the Rev. W. Sidgreaves, the relationship of magnetic deflections to the lie of the measures was well shown. There is an important peak near King's Lynn and a ridge line passes from Lynn to the east of Lincoln and east of Leeds to a little north of Giggleswick in Lancashire. The hard coal-seam in Nottinghamshire thins considerably towards the east, and if such thinning continues colliery extensions towards the east must be hazardous experiments.

The President proposed a vote of thanks to Mr. Coke for his paper, which was cordially adopted.

Mr. Coke, in acknowledging the vote of thanks, said that the results of the Owthorpe borehole were to some extent matters of opinion, and

until the full section was published they would remain so. He thought that this Institution might request Parliament to cause the 6 inches scale geological map of the districts of the hidden Coal-measures to be undertaken. He knew that the Geological Survey department would be quite willing to do it if they got the necessary funds. Referring to Mr. Mills' remarks, he did not wish to "water his coal" too much. There were several faults south of Clifton colliery, and he did not think that coal would be worked in the immediate future south of those faults. As to the possible anticlinal he did give it a thought at the time, but after hearing Prof. Hull's paper on the eastern limits of the Midland coal-field,* he found that there was no room for any large area of coal between the southern side of such an anticlinal and the boundary Prof. Hull imagined. He believed that there were indications of a considerable disturbance passing from the north part of the coal-field somewhere to the east of Burton Joyce.

The following paper by Mr. A. G. Charleton on "The Indian Gold-fields" was taken as read:—

* *Trans. Fed. Inst.*, vol. xi., page 9.

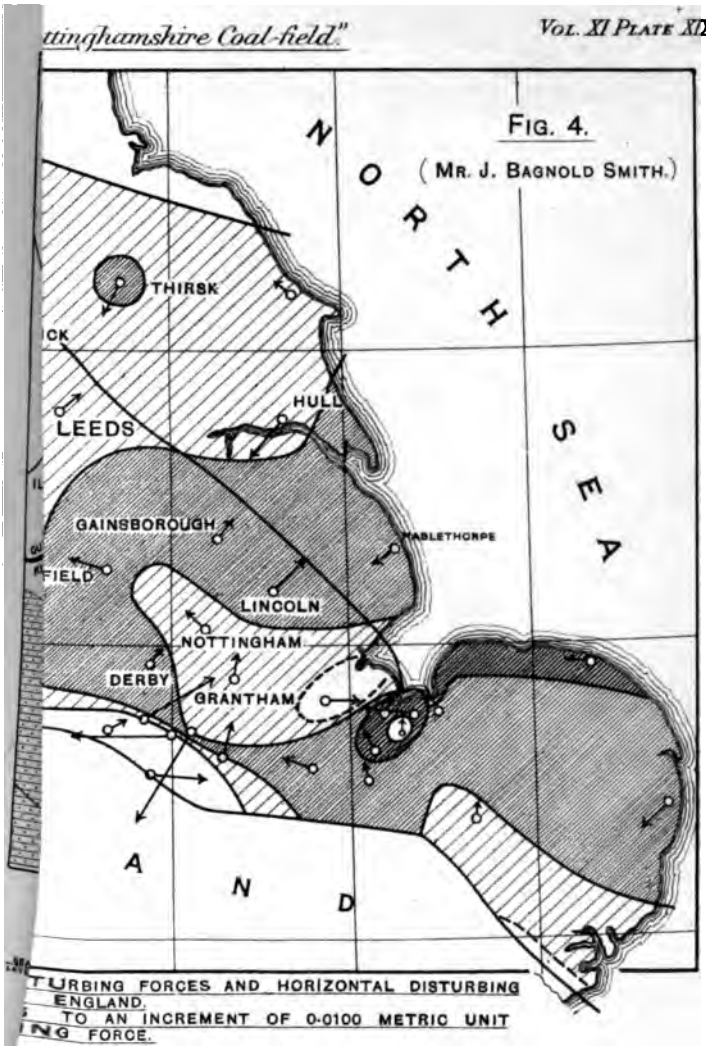


FIG. 4.

(MR. J. BAGNOLD SMITH.)

URBING FORCES AND HORIZONTAL DISTURBING
ENGLAND.
TO AN INCREMENT OF 0·0100 METRIC UNIT
NG FORCE.

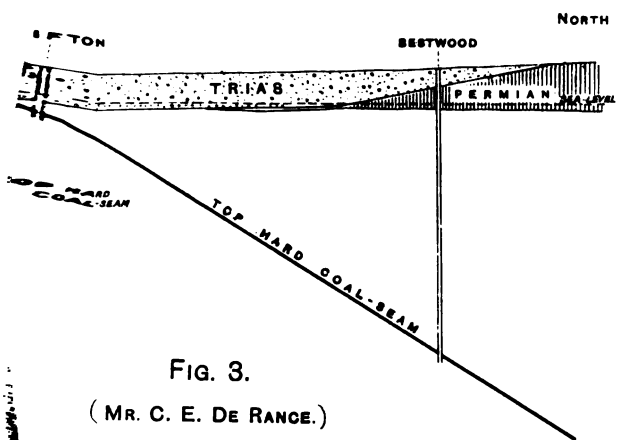


FIG. 3.

(MR. C. E. DE RANCE.)

Horizontal Scale, 8 Miles to 1 Inch.
Vertical Scale, 800 Feet to 1 Inch.

THE INDIAN GOLD-FIELDS.

By A. G. CHARLETON.

Introduction.

In ancient times, it would appear that India produced immense quantities of gold, and if history and legend are founded on fact, it seems probable that rich gold-fields may be re-discovered in parts of the country which are at present unknown to the Anglo-Saxon miner. It would not be surprising if such were the case, as, apart from the excellent work done by the Geological Survey of India, the country has never been properly prospected, and indeed rarely, if ever, visited by the prospector, who has been the pioneer of mining enterprise in other parts of the world, where the mining laws and the tenure under which land is held, throw the country open to him to "peg out" claims on his own account.

Mr. Mervyn Smith* is the writer's authority for the following historical facts. He states that Prof. Max Müller and Mr. W. Eastwick have advanced various arguments to prove that India is the Ophir of Scripture, a district from which King David is estimated by Dr. Napier to have derived £940,000,000; two-thirds being in gold. Whether this view is correct or not, it is likely to remain an open question, but, 500 years later, in B.C. 480, Darius, the Persian, seems to have undoubtedly levied and obtained from India an annual tribute of £3,250,000 in gold.

"There is a Buddhist legend of the purchase of a garden at Sravasti, when the owner, Prince Jota, demanded as its price, that the purchaser should cover the whole surface with gold coins touching one another. This condition is said to have been fulfilled, and the value of the gold coins has been computed at £16,000,000." A bas-relief of about B.C. 250, in the temple of Gaya in India (a photograph of which may be seen in the British Museum), represents the incident.

"Megasthenes, the Greek ambassador at the court of Sandracothus, the Indian emperor, speaks of gold-dust being commonly used by the Indians as money."

In more recent times, historians describe the enormous wealth captured by Mahomed of Ghazni in his ten expeditions to India. In the last and most famous one, the value of the gold alone obtained on the destruction of the temple of Somnath, has been estimated at £12,000,000.

* *Trans. Institution of Mining and Metallurgy*, vol. i., page 313.

The wealth of India has attracted successively the attention of the Persians, Greeks, Romans, Arabs, Tartars, Moguls, Portuguese, French, and British.

When impeached in the House of Commons for accepting bribes in India, Lord Clive (after describing the enormous wealth spread out before him in the treasure-vaults of Moorshedabad, when he was desired to take as much as he pleased and only accepted £100,000) exclaimed, "By God, gentlemen, I wonder at my own moderation!"

"In the Rig-veda (Hindu scriptures), mention is made of small bags of gold-dust (pindan) as being current among the Hindus. Little bags of gold-dust (phitang) are still in use as money in Kumaon and other Himalayan districts."

"The Satapatha Brathmana, another of the Hindu sacred books, speaks of bags of yellow gold."

"Pliny, in A.D. 77, referred to the country of the Nareae as containing numerous mines of gold and silver;" and this has been identified with Malabar, on the west of Mysore. "Pliny also describes the working of the gold-mines in Kaspatyrus (Kashmir), and speaks of a mining pick made of horn, used by the Indian miners, being preserved in the temple of Hercules at Erythroe."

Although nearly 2,000 years have since elapsed, yet, at the present day, mining is still carried on in this locality with a pick precisely the same, made of the horn of the wild-sheep, tipped with iron, mounted on a wooden handle.

Gold is known to occur in all the great divisions of India: in the Central Provinces, Punjaub, North-West Provinces, Burmah, the Nizam's dominions, and many of the native states. The late Prof. V. Ball (at one time of the Geological Survey of India), in the *Manual of the Geology of India*,* gives a list of 75 districts, covering an area of many thousands of square miles, where gold is washed by the natives.

In our own time, mining has been most extensively carried on by European methods in two entirely distinct districts in British India.

(1) The Wynaad, a plateau hemmed in by the Nilgherry and Koondah hills on the east and south-east, the high table-lands of Mysore and Coorg on the north, and the Vellery Mulla range on the west.

(2) The Colar district of Mysore, in the southern part of the peninsula, between the Eastern and Western Ghauts south of latitude 15 degs. north.

* Part 3, Economic Geology, page 173.

(3) Some work has also been done recently in the Chota-Nagpur district in Bengal, but so far as the writer is aware, without very encouraging results up to date.

Mr. Mervyn Smith * says that :—

> Schistose rocks superimposed unconformably on gneiss or other metamorphic rocks (of which we have an example in Colar), are in India the great depositories of gold, and embrace chloritic, talcose, ferruginous, micaceous, and argillaceous members of the series, the two first-named being found, so far, the most favourable class of country; whilst the gold has only been met with in workable quantities in a quartz matrix. Quartz-reefs are found traversing the schist and the underlying gneiss, but it is only in the schist that they have been found payable, although a little gold has been found in the reefs in the gneiss.

The writer's own experience confirms this statement.

In southern India, the gold-bearing schists are known as the Dharwars, from a town in the Bombay Presidency where they are very prominent. In northern India they are termed sub-metamorphic.

Dykes of diorite and dolerite are often found cutting through the schists and reefs, and displacing or faulting the latter. In many parts of the country the schists are covered over for miles with a sheet of trap rock, whether from an overflow of the molten rock when the dykes were formed, or from certain volcanic centres, has not been ascertained. This overlying trap weathers into what is known as the black cotton-soil of India—one of the most fertile soils in the world.

It is impossible to estimate the thickness of the schistose series, but too much stress cannot be laid on the fact that the depth of the pay-rock is unlikely to be more than the thickness of the schists in which it occurs, and where they are underlain by gneiss the reefs may probably be found to disappear totally, should mining work ever reach such a depth. There is evidence that the schistose series at one time prevailed over larger areas than it does now. The tremendous influence of the monsoons has, where their action is most felt, almost entirely denuded it, as on the Western and Eastern Ghauts.

Outlying patches made up chiefly of the harder members of the schistose series, and surrounded by the more crystalline rocks, are found here and there at widespread intervals.

It is possible that ancient "leads" or river-beds similar to those discovered in Australia and America, may be discovered on these fields where they are covered by an overflow of trap, yet up to date no tangible evidence exists of their occurrence in India.

* *Trans. Inst. of Mining and Metallurgy*, vol. i., page 317.

Conglomerates resulting from the denudation of the older schistose rocks are found in various parts of the peninsula, and these have been proved auriferous.

Mr. Smith is of opinion that the gold-dust, obtained in such enormous quantities in ancient times in northern India, came from the Tertiary rocks found along the foothills of the Himalayas from east to west, these rocks being the product of disintegration of the metamorphic rocks which make up the mass of these mountains.

It is to be noted that the gold-bearing rocks of Manicaland and Matabeleland in Africa appear to bear a striking resemblance to those of India.

Mr. C. J. Alford, in a published report,* states that :—

The geological features of the former district present themselves as a base of granitic and gneissic rocks, overlain in places by the denuded remains of beds of crystalline schists and slates with which the older rocks were once covered.

These, together with the granitic rocks, are repeatedly pierced by intrusions of trappean rocks in the form of dykes and sheets, and the whole has been subjected to a long period of sub-aerial denudation, by which the valleys have been filled and the hillsides covered with masses of detritus hundreds of feet in depth, in which the streams have worn their courses, and added to the general complication, many series of more and more recent surface-deposits.

The sharp ranges of hills running east and west are of crystalline schists, but it is rarely, except at or near the summits that an exposure of rock *in situ* can be met with. The results of contact-metamorphism, at the junction between the intrusions of trap and the schists, are in places strikingly apparent in the resulting development of minerals, and in the highly crystalline structure produced in the penetrated rocks.

In the cleavage-planes of the slaty rocks veins of quartz are abundant, varying from mere threads to many feet in width, and in many cases these have been found to be highly auriferous, from which circumstance the east and west zone of hills containing them has been called the "gold belt," and this can be followed varying in width from one to three or four miles from the east of Massi Kessi to the Odzi river and far beyond into Mashonaland.

There is not wanting in these rocks evidence of fissure-veins containing gold with other minerals, but little is yet known of the country. It may be, indeed, that discoveries, equal in importance to those which have been made in India and the Transvaal, will reward the energy of the enterprising prospector who has scarcely yet penetrated into this part of the world. That gold has been worked in Manica and Mashonaland in times past is amply testified by the old workings. Along many of the hills in the Manica country the whole surface is scored with pits, and the valleys and alluvial ground have been turned over for miles.

It is to be remembered that it was by following such indications, in spite of much discouragement at first, that the value of the Mysore gold-fields was demonstrated, and it was only in depth that their significance became apparent. Probably history may be found to repeat itself in this connexion in South Africa.

* *Mining Journal*, March 18th, 1893, page 299.

It would be dangerous also to assume without trial that the granite or gneissic rocks of Africa or other localities will bear out the evidence of unproductiveness found in parts of India, since elsewhere (as, for instance, in Queensland and Colorado), payable deposits of gold have been worked in granite and in gneiss.

Whilst the schistose and slaty rocks, under favourable geological conditions, appear to be most often the repositories of the precious metals, it often happens that veins of remarkable permanency, carrying a good pay average of gold are found in granite or syenite country, as in California, though here again instances of an exactly opposite character might be cited. There is really no invariable rule determining the occurrence of gold; each case must be judged on its own merits, and the Cornish axiom, "Where it is, there it is," is the only generalization that can be laid down with absolute certainty.

Wynaad District.

This field lies at a general elevation of some 3,000 feet above sea-level, at the eastern foot of the Nilgherry hills, which rise above the Wynaad about 3,000 feet.* It consists of an assemblage of conical hills of nearly equal height, packed as closely together as they can stand, like a collection of tents, leading one to think that their summits probably represent the original level of what was once a table-land, since sculptured into its present shape by the denuding action of water and climate.

In the midst of this plateau, at some distance apart, there are, however, three or four district ranges of hills, rising above the general surrounding level. The principal one, upon the slopes of which most of the important mines of the district are situated, is traceable from Needle-rock to Hadiabetta, which are the points of highest elevation in the Wynaad.

A lower line of hills lies beyond this main range and the coast, to the west; while south-east of the Needlerock-Hadiabetta range, the Old and Carcoor ghâts (on which the Perseverance and Indian gold-mines estates are respectively situated) run nearly parallel with the Koondahs.

It looks, in fact, as if the country had originally been crumpled into several folds from the direction of the Nilgherry hills, and as the main ridge, instead of running in a straight line from end to end, is bent more or less into a bow, it may be, that whilst upheaval was going on, the strata forming these hills were subjected to longitudinal compression by the Koondahs and Vellery Mulla hills acting like dead-weights at their

* Ootacamund is at an elevation of between 7,500 and 8,000 feet.

extremities. In point of fact, one finds that these ridges have been bent into folds longitudinally, forming wave-like saddles and peaks, and subjected to intense metamorphism.

Needlerock, as its name implies, is a sharp pointed peak, but the other hills are rounded rather than abrupt.

In the neighbouring section of the Nilgherries to the east, the country-rock consists of diorite, diabase, granite, and hornblendic rocks, which cover areas of more or less extent.

In the Wynaad itself a complete change has taken place, and one finds the country-rock almost entirely composed of grey gneiss, extremely hard to drive in, overlain by a red variety of the same rock, while in some places the gneiss has been partially altered and becomes chloritic, hornblendic, or granitoid in character. Intrusive rocks are exposed here and there, notably a remarkable dyke, which forms the backbone of the Needlerock, and can be traced, it is said, to Hadiabetta peak ; and an intrusive sheet of greenstone-porphyry on the Dunbar estate.

Three distinct classes of gold deposits are met with in the district :—

(*a*) A system of lenticular inclusions or beds of quartz, hard, white, and sugary looking, poor in gold and sulphides, and split into more or less rectangular blocks, by joint-planes at right angles to the bedding of the country. The deposits of this class generally conform to the bedding-planes of the red gneiss, are contorted with it and split into strings or wedge out when they get into the underlying grey gneiss, while the mineral they contain lies mostly between the joints of the quartz, at right angles to the walls.

(*b*) A series of lodes running parallel with the main line of foot-hills, striking generally 15 to 40 degs. to the east or west of north, with a dip of 30 to 45 degs. to the north-west or east (generally eastward).

(*c*) Alluvial deposits.

While explorations in depth have placed beyond a doubt the existence of lodes belonging to class (*b*) living down into the country-rock at a depth too great to admit of their being affected by surface agencies, by far the larger number of reefs belong to class (*a*). These latter show a want of continuity in strike and dip, under circumstances which might, however, lead a casual observer to suppose that they were persistent in both.

What would appear at the surface to be a continuous outcrop of quartz often proves on investigation by a cross-trench to be nothing more than a symmetrically disposed row of superficial boulders, sufficiently angular notwithstanding to justify a hasty supposition that they were *in situ*.

In other cases, what seemed to be a strong reef dipping into the hill-side was proved by cross-cutting it to wedge out in a few feet, and still more commonly the quartz was found to conform to the slope of the hill-sides. When the overlying rock had been entirely denuded away, this gave rise to the float quartz, amounting to thousands of tons (many single boulders being of immense size), which is found strewn over the district in many places.

Where this happened the hard quartz has, no doubt, acted as a blanket, shielding the rocks below from the further destructive and disintegrating effects of later monsoons. Faults are very common, and landslips, which occur frequently during and subsequently to the monsoon, have also beyond doubt dislocated the exposed outcrops of the reefs, and led in some cases to what was really part of the same outcrop being mistaken for the exposure of a second and parallel vein. The quartz-reefs, which are hard, white, and semi-vitreous, sometimes crystalline and barren, are often highly laminated, parallel to the strike, near the surface, and vary in thickness from a few inches to 15 or 20 feet in width. The gold in them is mostly free and of a fine character, but is generally associated with iron pyrites, of which the stone often carries from 2 to 5 per cent., besides small quantities of copper-pyrites arsenical-pyrites, and magnetite.

No doubt can exist of the extent of mining operations which were carried on in this district in periods more or less remote, the date of which cannot be fixed.

In a country which has been subjected for centuries to the tyranny and caprice of native rulers, and devastated periodically by the sword, famine, and epidemics, the scanty population becomes too engrossed in the struggle for existence to feel much interest in the conditions under which its predecessors obtained a livelihood.

Still, substantial evidences of a bygone mining industry exist at a number of points in the Wynaad. Old native tunnels and workings are scattered all over the country, and shafts have been re-opened sunk to a depth of over 70 feet.

On the Palmerston estate as many as thirty-two native shafts of this description were sunk within an area of 300 square feet, ranged in parallel rows They mostly average about 4 feet square, and a sort of winding spiral footway cut in the sides was evidently used by the old miners as a means of communication with the surface.

The motive that induced the natives to sink at this particular spot in such close proximity can only be guessed at. It is possible that the

first was put down as a venture, and proved sufficiently remunerative to attract attention to the spot, and that claims may have been located independently of one another round the point where the first discovery was made.

The chief point of present interest is to know why these shafts were sunk at all, as this is not an isolated case, but one of many which may be seen in the neighbourhood.

In this particular instance the shafts passed through the red gneiss into a flat gossany deposit, stained heavily with iron and copper, covered by an indurated, almost non-auriferous, bed of sand in rounded grains on which the old miners appear to have done a good deal of work, parallel with two or three irregular layers of quartz, ½ inch to 2 inches wide, in the country-rock above.

The number of ancient workings of this kind scattered over the Wynaad has had a most important bearing on the history of this district, as they probably first drew attention to the existence of the reefs, and led to the belief that gold would be found in considerable quantities, sufficient to pay for the trouble of sinking.

The writer's own view is that the natives were acquainted with the fact that the quartz often followed the natural bedding of the country-rock, and that, therefore, however contorted the reef might be, a vertical shaft would cut it at a certain depth like a bed of coal.

As each recurring monsoon may have more or less filled the shaft up, it is, of course, possible that a reef below these old workings may have been the real object that the natives sank for.

Though the stone of the district has occasionally given high assays, going up to 25 ozs. and even 204 ozs. 11 dwts. per ton, milling it in bulk has seldom returned more than 1½ to 5 dwts. of gold per ton,* worth about £3 17s. 10d. per oz.

The cost of shaft-sinking was reckoned in 1884 at Rs.12 to Rs.25 per foot, according to depth; driving levels, 7 feet by 6 feet, at Rs.7 to Rs.12 per foot; and winzes, rises, and cross-cuts at Rs.14 per foot by contract. Stoping on contract cost about Rs.1 10a. to Rs.3 8a. per ton, and in a drive all in ore at a rate of advance of, say, 7 feet per week the stone would probably have cost Rs.2 14a. 4p. per ton. In tight ground, 16 per cent. might be added to these latter costs.

In 1884, the author reckoned that mining and milling 800 tons per month, at a mine he reported upon in the Wynaad, taking into considera-

* Crushings of selected stone in small quantities have, however, given 7 to 8 dwts.

tion the size of the lode and the conditions for mining it that obtained there, a yield of at least 5½ dwts. (valuing a dwt. of gold at 3s. 6d.) would be required to cover all expenses before anything could be set aside for interest or redemption of capital. As this amount does not include dead-work, 7 dwts. per ton at least would, the writer reckoned, be required to pay all costs. With improved communication, strictly economical management, more suitable machinery, and cheaper labour afterwards introduced, the mining and milling costs could, however, in all probability be covered by 3½ to 4 dwts. per ton.

The following shows the writer's estimate of cost, based on actual working results, with prices ruling at that time (1884):—*

	Rs. A. P.	s. d.	Rs. A. P.	£ s. d.
Average cost of mining and general expenditure per ton	8 9 1	14 3¼	to 9 4 2	0 15 5½†
Average cost of company's London expenses	2 3 6	3 8¼	,, 2 8 0	0 4 2
Average cost of milling	0 11 3	1 2	,, 1 9 5	0 2 7¾‡
	11 7 10	19 1¼	,, 13 5 7	1 2 3

† Mining costs—

	Per Ton. s. d.
Supervision and haulage	1 6¾
Native labour	5 10
Explosives	3 7
Timber	0 3¾
Candles	0 5½
Steel and iron	0 4¾
Oil and tallow	0 1¼
General stores	1 0½
	13 3½
Local administration and office expenses ...	2 1¾
	15 5¼

‡ Milling costs—

	Per Ton. s. d.
Native labour	0 11
Shoes, dies, and castings..	0 7¼
Oil and tallow	0 0¼
General stores, including mercury	1 1¼
	2 7¾

Mining the ore by adit tunnels, cheap timber, and good water-power account in some measure for these low charges.

For many years before it attracted attention as an auriferous district, the Wynaad was cultivated for coffee, the first estate being planted by

* The rupee was reckoned at 1s. 8d.

Colonel Ouchterlony some forty years ago. A large portion of the jungle has since been cleared, good roads have been made, and extensive areas have been laid out in cinchona, but a great part of the country is still covered with forests.

The climate during the greater part of the year is temperate and agreeable, except in the fever months, March to May, but during the monsoon, from May to October, the rainfall averages 150 to 200 inches, and has even been known to exceed 400 inches in places.

The gold washed down in this way from the hills built up an extensive native gold-washing industry amongst a tribe known as Koorumbers, who to this day wash the river-sands in a kind of batea or wooden-pan.

The native Rajahs appear from time immemorial to have levied a tribute in gold on the Koorumbers engaged in this pursuit, and the accumulations of the precious metal amassed by this means in long periods of time no doubt led to an entirely false impression of the richness of the gold deposits from which it was derived.

Gold which might pay an Indian Rajah to work, with what might be considered slave labour, would and did prove a disastrous failure for European companies who attempted to mine with a hired staff. There was no lack of either quartz or gold, but unfortunately it was too generally distributed to pay in any one place.

Companies were formed, and £4,500,000 are said to have been invested in this field without any tangible result except to throw discredit on the industry of gold-mining in India, which (happier results in Mysore notwithstanding) it will take years for the country to wholly recover from. Nor was this all. A great deal of money was unfortunately squandered recklessly on useless machinery, some of which was never even delivered. It was a melancholy sight to see parts of machinery, as they might be seen a few years ago, actually rusting by the roadside where they were dumped down.

A number of mining companies were formed about 1876, but with the utmost economy practised in later years, none of these undertakings have ever paid a dividend on their capital from gold won in the Wynaad, or are likely to do so, as all of them have, the author believes, suspended active operations, and with one or two exceptions are in liquidation, while those that survive have turned their attention to mining in other more promising fields.

The treatment of the ore throughout the district was practically the same at the various mills, stamping it and catching the gold partly in the box with mercury, partly on copper-plates, and in wells outside.

The pyrites which escaped was then concentrated either on end-bump tables or blankets, and the concentrates were ground in wheeler-pans or berdans, while the sludge that escaped was usually re-treated by passing it through tyrolean mills before allowing it to escape to the catch-pits. This process, under the most favourable conditions, extracted about 76·2 per cent. of the total gold contents of the ore.

The crude treatment of the pyrites could, it is true, have been improved upon, by which the returns might have been raised higher, but having to deal with low-grade concentrates, the writer does not think that chlorination, or any other more elaborate methods proposed, could ever have yielded better commercial results, even with closer concentration than that generally obtained.

The writer believes that the total production of the district obtained by English mining companies can be put down to date at less than 18,000 ounces of gold.

Madras Gold-field.

The chief mines of this group are in the Mysore district, about 9 or 10 miles from Colar Road station, on the Bangalore branch of the Madras railway, at an average elevation of 2,800 feet above sea-level. The distance by rail from Madras is about 150 miles, and is done in about 8 hours. Bangalore, a military station of some importance, is about 35 miles distant.

From Colar station there is a good road to the mines, and a branch railway has quite recently been built to connect them with Colar Road junction.

The country, along this line of road, when the writer visited it a few years ago, was a flat, barren, almost treeless, plain, covered with scanty grass and a few stunted trees and bushes, though in the nullahs and more sheltered spots where there was water, there was more vegetation, and here and there paddy-fields and other signs of cultivation might be seen.

Around Colar Road station the country-rock is almost entirely syenite and granite, traversed by strings of quartz, but further north its geological aspect changes, and over a low quartzite ridge there is a belt of metamorphic, crystalline, chloritic, and talcose schists, which are at a slightly higher elevation than the granite to the south.

The schistose rocks form an elevated plain or plateau, in fact, which is bounded still further to the north by a belt of older plutonic rocks, corresponding to those which lie to the south.

It would seem as if the altered schistose country (which in places is almost converted into slate) in which the reefs occur had been wedged in

between the granite on either side, and puckered into one or more folds, which have since been planed down to a dead level by the denuding agency which has acted on them, leaving a rim of the harder quartzite standing at the line of contact, the low ridge (20 or 30 feet high) of which mention has been made.

As there is very little to be seen of the outcrops at the surface, although there is an abundance of angular quartz scattered about the surface, the plan has been adopted throughout the district of sinking shafts in the neighbourhood of the depressions which mark the site of old native workings, in order to intersect the several reefs in depth.

The champion reef can be traced by these old workings for a distance of about 3½ miles, possessing an average width of about 3 feet, widening in places from a thread to massive makes, 13 feet or more wide. It has been actually proved by levels and workings for a length of about 3 miles, and in the Ooregum mine one pay shoot, averaging 2½ feet in width, has been proved for 1,000 feet in length, between the 280 and 560 feet levels, and is said to have averaged by assay 2½ ounces per ton. The aggregate length of the shoots of pay-ore so far proved is said to be 13,740 feet or about 2½ miles. A ribboned or laminated structure is apparent near the walls of the lode.

The field is traversed by dykes of diorite or basalt, some being of great size. The main basaltic dyke coursing north and south approximately parallel to the champion lode is generally considered to be dolerite, and is said to be over 200 feet thick in places. It has been traced for over 10 miles in length, and has a slight easterly dip, intersecting the champion reef (which dips west), in depth, and heaving it about 50 feet to the west, near Rowse shaft.

Granite, east and west cross-courses also occur, one of which in the Nundydroog property throws the lode to the east about 70 feet on the side of the greater angle.

The champion reef has, it is stated, yielded over £10,000,000 of gold within the last few years (since 1884, when rich ore was first struck).

West of the champion reef is a lode known as Mallesons, the ore of which is extremely pyritous.

The main run of the dykes appears nearly parallel with the strike of the reefs, and the ore of the champion lode is singularly free from pyrites, though the Nundydroog ore carries some galena, which is considered a favourable indication; the ore, however, as a rule is very free milling, and here and there the gold is coarse and plainly visible to the naked eye. It is these portions of the reef that the natives followed, but it is more usually finely disseminated in the gangue.

The light blue-coloured, semi-transparent quartz characteristic of these lodes is often very rich.

The dip of the Mysore lode which was to the west 50 degs. near the surface gradually flattened to about 31 degs., where it was intersected by the dyke, and continued flat for some distance below the point of intersection. Mr. J. Garland has also drawn attention* to the folding to which the lode has been frequently subjected. In following the lode northward, for instance, a sharp bend is met with, the lode doubling back on itself, this on being followed southward for a great many feet (sometimes 100 or more) presently leads to another sharp bend back again northwards, and thus a double fold not unlike the letter S is formed, and the branches or limbs of the fold are often found to be very rich. It may be mentioned that any given fold generally re-appears in the deeper levels but further north, thus agreeing with the shoots of ore in having a northerly dip.

Some of the ancient workings in the Mysore gold-mines were found to extend to a depth of 309 feet from the surface. All the pay shoots on the field have a northerly dip.

Mr. Mervyn Smith states that up to December, 1892, the Mysore, Ooregum, and Nundydroog Companies had crushed 206,000 tons of quartz, yielding 402,000 ounces of gold, an average of nearly 2 ounces per ton.

If the country around Colar is uninteresting, the phenomenal richness of the field, which for its size will compare favourably with any the writer has seen in any part of the world, gives it from a mining point of view, a special interest. The value of the gold produced by the Mysore, Ooregum, and Nundydroog mines has shown a steady increase from year to year.

Working Details of Several Representative Gold-mines.

The average grade of the ore in the Mysore gold-mine appears to have fallen from 1 ounce 9 dwts. 18 grs. in 1892 to 1 ounce 0 dwts. 19 grs. in 1895, the larger output naturally tending to reduce its average value. But, on the other hand, the percentage of extraction seems to have improved, as shown by the following figures:—

	1892. Per Cent.		1895. Per Cent.
Average extraction of gold by milling	76·9	...	78·15
,, ,, tailings treatment	13·5	...	14·61
Total extraction of gold	90·4	...	92·76

In 1895, the average assay of the sands dealt with in the cyanide works is stated to have been 4 dwts. 20 grs. (the tailings after treatment

* "Presidential Address," *Institution of Mining and Metallurgy*, 1896.

containing 1 dwt. 16 grs.). The gold obtained was 0·850 fine; the consumption amounted to 29,287 lbs. of 72 per cent. cyanide of potassium, equal to 1·62 lbs. per ton of ore treated, or 1·16 lbs. of pure cyanide of potassium. The consumption of zinc shavings was 4,111 lbs., or 0·227 lb. per ton. The sands treated most successfully were chiefly taken from an old heap, and the treatment of sands direct from the mills is said not to have been the success that was anticipated. The managers of the mine seem to be of opinion that the success of the process in dealing with the Mysore ore depends in a large measure on the degree of fineness to which the ore is crushed. The cost of treating 18,065 tons of tailings by this process is stated to have been 5s. 8½d. per ton.

The gross working expenses at the Mysore and Nundydroog gold-mines (given in Tables III. and IV.) may be subdivided as follows: —

	Mysore.				Nundydroog.			
	1892.		1895.		1892.		1895.	
	s.	d.	s.	d.	s.	d.	s.	d.
‡Mining	24	7	21	1·78	30	5¼	24	3·82
‡Milling (including tailings treatment)	14	0¼	*12	2·24	8	6½	†6	4·74
General expenses	3	1½	2	2·93	3	1¾	2	0·04
Management	2	5¾	1	5·10	2	10½	1	11·15
London expenses	2	6¼	1	9·89	4	1	2	3·63
Totals ..	46	8¾	38	9·94	49	1¼	36	11·38

* Of this amount 6s. 5·74d. is reckoned on account of tailings treatment by amalgamation and cyanide.
† Of this amount 1s. 8·43d. is chargeable to tailings treatment by amalgamation.
‡ An analysis of these costs in detail is shown in Table V.

The relatively higher costs of mining, management, and general expenses at Nundydroog compared with Mysore (as shown by the preceding table) it should be pointed out are obviously due to smaller output. The "country rock" in Nundydroog mine is also said to be exceptionally hard (a kind of hornblende-rock), harder than quartz itself. Table I. gives the size and value of the lode in various workings in the several leading mines of the field in 1892 and 1895.

In 1892, picking-floors were erected at the Mysore gold-mine at the Rowse shaft, the quartz being delivered at a high level, tipped over screens, and after crushing passed into hoppers, from which it could be run into trams and distributed to the mills. The economy thus effected in handling and concentrating all stone-breaker work and picking at one point ought to be beneficial, so long as all chance of theft by the natives in picking is avoided. No. 3 mill and tailings machinery, which was also built during 1892, consists of two compound condensing engines, with cylinders 30 inches in diameter and 3 feet stroke, 4 Cornish boilers, 30 heads of stamps with amalgamating-tables, 18 wheeler-pans, and 6 settlers.

A 20 heads stamp mill was erected at the Nundydroog gold-mine in 1892, and the weight of the stamps was 850 lbs., as compared with 750 lbs. in the old mill. The tailings-plant attached consists of ten pans and three settlers, capable of dealing with about 650 tons a month. Electric signalling was introduced at this mine in 1892, and was found a great improvement over the knocker-line. In 1895, a new mill of thirty heads of stamps, with power for forty, was in course of erection. The average fineness of Nundydroog gold was 0·885 in 1892, and its value was reckoned at £3 15s. 4½d. per ounce.

The Ooregum Company, which previously possessed a battery of 30 stamps, erected a 40 heads mill in 1892, with tailings machinery consisting of 36 wheeler-pans and 18 settlers, having a capacity of 36,000 tons per annum. Two 5 feet wheeler-pans and one 8 feet settler were employed for treating blanket-sand. There is a Blake-Marsden stone-breaker in each mill. It is reckoned that eighteen wheeler-pans and nine settlers cost £10,000 to erect, the initial price of the machinery in England being but a small part of the gross cost. The company possessed twenty steam-engines and thirty-six boilers in 1892, which consumed 1,500 tons of coal monthly; this represents a coal consumption of 8 lbs. per indicated horse-power, notwithstanding the use of high-class compound condensing-engines automatically lubricated with hydrocarbon oils, running at a suitable piston speed, with steam at a pressure of 100 lbs. per square inch, and is said to be in a great measure due to the inferior skill of the coolie firemen. Multitubular boilers have been tried and found less economical than the Cornish pattern fitted with Galloway tubes. The company possessed a reservoir holding 800,000 gallons of water, and 2½ miles of pipes had been laid in 1892 in connexion with their works.

The Ooregum mine costs in 1892 represented, it is said, 42 per cent. of the value of the gold produced after deducting royalty. In 1889, the cost of winning each ounce of gold at this mine is stated to have been £2 13s., £2 2s. 8d. in 1890, £1 19s. 9½d. in 1891, and £1 9s. 9½d. in 1892. There was a reserve of 23,055 tons of tailings still on hand at the end of 1895, about 9,945 tons having been worked up in 1895 from the accumulated heap.

The air-compressing plant at the Champion Reef gold-mines operates thirty-eight Climax rock-drills. Other mines in this district are the Mysore West, Mysore Wynaad, Coromandel, South-east Mysore, Mysore Reefs, Colar Central, Gold-fields of Mysore, and Nine Reefs.

The Kempinkote property, situated some 140 miles from C being worked by the old Indian Consolidated Company (in liqu to test an old native working of exceptional dimensions.

Tables III. and IV. show the returns of the principal mine Colar gold-field. The difference in "exchange," it should be poi is a factor which largely favours gold-mining in India, and oth countries, as in a gold-standard country the costs measured in would naturally be higher.

The author is indebted to Messrs. John Taylor and Sons for at his disposal the reports of the several companies from wl statistics given have been taken except where otherwise stated.

TABLE I.—MYSORE GOLD-MINE.

Date.	Section of Mine.	Length of Shoot. Ft.	Ins.	Average Size of Lode. Ft.	Ins.	Average Value per Ton Ozs.	D.	G.
1892	—North of Rowse shaft (west of dyke) ...	—		3	4	2	0	0
,,	—Workings near Gilbert's shaft...	—		2	6	1	0	0
1895	—Crocker shoot, near Rowse shaft, 780 feet level	216	6	3	1	1	9	9
,,	,, ,, ,, 1,060 ,,	260	0	6	0	1	17	17
,,	,, ,, ,, 1,160 ,,	41	0	5	6	2	0	0
,,	,, south drift 1,260 ,,	20	6	*5	0	1	15	0
	NUNDYDROOG GOLD-MINE.							
1892	— 760 feet level, north	—		3	0	1	18	2
,,	— 600 ,, south, No. 1 stope	—		6	0	1	16	6
,,	— 520 ,, ,, intermediate north stope	—		5	6	2	10	3
,,	— 520 ,, ,, ,, south stope	—		6	0	2	10	6
1895	—1,080 ,, north	237	6	3	6	1	10	0
,,	— 700 ,, Kennedy shaft, cross-cut ...	—		3	0	0	18	18
,,	— 600 ,, south of Kennedy shaft ...	283	0	2	0	0 3	1 5	21 0
,,	— 370 ,, ,, ,, ...	300	0	2	0	1	10	0
,,	— 250 ,, ,, ...	250	0	1	3	1	0	0
,,	— 230 ,, south of north shaft	203	0	1	0	1	6	6
	OOREGUM GOLD-MINE.†							
1892	— 430 ,, cross-cut, west of Low shaft, north drive	52	9	1	0	4	10	19
,,	— 430 ,, cross-cut, west of Low shaft, south drive			1	1	6	10	16
,,	— 430 ,, cross-cut, west of Low shaft, No. 2 shoot	63	0	1	6	5	16	23
,,	— 560 ,, north of Wallroth shaft ...	62	0	1	9	4	15	22
,,	— 280 ,, south ,, ,, No. 2 shoot‡	462	0	5	0	2	1	3
1895	—Taylor shaft	228	0	2	10	2	5	12
,,	—760 feet level, south of Taylor shaft	476	0	2	2	2	14	11
,,	—760 ,, north ,, ...	118	6	2	7	1	16	2
,,	—660 ,, south ,, ...	481	0	1	7	1	16	14
,,	—560 ,, ,, ,, ...	285	0	2	2	1	16	7
	CHAMPION REEFS GOLD-MINE.							
1892	—200 and 240 feet levels, Ribblesdale shaft, north and south of cross-cut	220	0	4	6	2	12	0
,,	—225 feet level, south of Carmichael shaft in cross-cut	lode cut		13	0	5	4	12
1895	—840 ,, north of Garland shaft ...	557	0	3	4	1	17	15
,,	—840 ,, stope	—		6	0	1	14	0
,,	—Garland shaft	187	0	1 5	3 6	2	11	4
,,	—440 feet level, west of Garland shaft, north of cross-cut	163	0	3	0	2	2	7
,,	—540 ,, north of Ribblesdale shaft, north of cross-cut	141	0	4	0	1	12	0
,,	—Inclined winze, bottom of 340 feet level, south of Ribblesdale shaft ...	221	3	4	0	1	17	0
,,	—415 feet level, north of Rowes shaft	168	3	1	6	2	10	0

* In places 13 feet wide, assaying 1 ounce 10 dwts.

† From the longitudinal section of the mine workings there appears to have been an almost continuous shoot of ore between the 280 and 560 feet levels, extending from north of Wallroth shaft to the southern boundary of the property for a length of over 1,500 feet.

‡ This shoot was driven on for 500 feet in 1891; it is therefore nearly 1,000 feet in length, averaging 4 feet 6 inches, with an average value of 2 ounces 9 dwts. 17 grs.

TABLE II.

Depth of Workings (1895)	Mysore. 1,520 feet.		Nundydroog. 1,244 feet, 6 inches.		Ooregum. 1,500 feet.		Champion Reef.* 959 feet.	
	1892.	1895.	1892.	1895.	1892.	1895.	1892.	1895.
Reserves of ore, tons	70,926	96,613	26,450	51,405	55,354	70,488	16,000	110,000
Number of Europeans employed	85	95	63	36	65	73	—	—
Average number of natives† employed	2,509	2,943	1,600 to 1,800	1,649§	1,662	2,431¶	—	—
Total number of workpeople (average)	2,594	3,038	1,763	1,685	1,727	2,504	—	—
Average number of rock-drills employed	30	43‡	12	20	24 to 26	34**	—	—
Ground driven—	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.		Feet. Ins.
Levels and cross-cuts	6,360 7	6,004 8	2,648 6	8,017 7	4,039 10	6,952 10	—	6,880 6
Rises	933 2	1,055 6	460 0	1,943 6	668 3	418 0	—	1,739 3
Shafts and winzes	1,239 9	1,665 5	849 6	433 3	1,909 10	3,339 3	—	2,418 0
Total feet	8,533 6	8,725 7	3,958 0	10,394 4	6,617 11	10,710 1	—	11,037 9
	Fathoms.	Fathoms. Ft.	Fathoms.	Fathoms.	Fathoms.	Fathoms.		Fathoms. Ft.
Stopes	2,899	4,386 2‖	1,367	1,236·97	1,706	4,166·75	—	4,512 4
Plats	—	—	50	36·50	—	56·25	—	200 0
	£ s. d.		£ s. d.		£ s. d.		£ s. d.	
Dividend paid in 1892	112,489 10 0		57,178 10 5		111,105 10 0		—	
Total dividends paid to the end of 1895	900,094 5 2		254,373 19 10		567,875 0 0		135,000 0 0	

* Crushing commenced July, 1892.

† Moplahs and Chermas make the best miners, whilst Wuddahs and Canarese are extensively employed on the surface.

‡ 35 run by natives.

§ Eurasians, 36; engineers and helpers, 67; carpenters and helpers, 39; blacksmiths and helpers, 53; engine-drivers and firemen, 82; rock-drill miners and assistants, 919; timbermen and assistants, 58; platelayers and pipe-fitters, 23; surface-labourers, 249; mill-hands, 114.

‖ The number of fathoms of ground stoped in 1895 exceeded the previous year by 345 fathoms, owing to the lode pinching in places, which involved the removal of a good deal of wall rock; this added to the extra-heavy timbering and deadwork caused thereby, swelled the mine charges.

¶ Eurasians, 47; carpenters, 29; smiths, 50; engine-drivers, 52; firemen, 91; underground coolies, 1,568; stamp coolies, 177; tailings coolies, 56; surface coolies, 36.

** 24 run by natives.

TABLE III.

Name of Gold-mine.	Period covered by Statistics.	Quartz Treated and Gold Extracted.			Tailings Treated and Gold Extracted.			Total Bar-gold Produced.	Standard Gold Sold.	Net Amount Realized	Total Cost Per Ton of Ore Mined.	Profit on the Year's Working.
		Quantity of Quartz Stamped.	Bar-gold Extracted.	Produce Per Ton of Quartz.	Quantity of Tailings Treated.	Bar-gold Extracted	Produce Per Ton of Tailings.					
	1892.	Tons.	Ozs.	Oz. dwt. gr.	Tons.	Ozs.	Oz. dwt. gr.	Ozs.	Ozs.	£ s. d.	£ s. d.	£ s. d.
Mysore ...	Jan. to Dec. (inclusive)	44,548	55,393	1 4 21	38,727	8,998	0 4 15	64,391	64,004·279	249,331 15 1	2 6 8¾	133,167 6 7
Nundydroog ...	Do.	18,176	29,214	1 12 3	5,950	2,009	0 6 18	31,223	30,155·373	117,635 5 9	2 9 1¼	67,604 11 8
Ooregum ...	Do.	24,041	49,191	2 0 22	16,699	4,645	0 5 13	53,836	51,836·034	202,249 14 8	3 6 7½	115,741 8 7
Balaghât ...	Do.	3,750* / 8,008†	6,976	1 17 5 / 0 17 10	Nil.	—	—	6,976	6,966·444	27,155 3 2	1 14 1¼	6,004 7 8
Champion Reef	July to Dec. (inclusive)	6,100	6,712	1 2 0	Nil.	—	—	6,712	6,563·523	25,627 9 2	—	—
Averages and totals ...		104,623	147,486	1 11 10	61,376	15,652	0 5 15	163,138	—	621,999 7 10	2 9 2	322,517 14 6

TABLE IV.

	1895.											
Mysore ...	Jan. to Dec.	60,654	58,855	0 19 10	38,597‡ / 18,065§	7,180 / 3,453	0 3 17 / 0 3 19	69,487	69,729·960	270,911 0 8	1 18 9½	140,601 3 11
Nundydroog ...	Do.	32,975	37,393	1 2 12	7,775	1,530	0 3 22	38,923	36,966·126	144,079 14 10	1 16 11	77,139 5 5
Ooregum ...	Do.	53,420	57,787	1 1 15	56,945	12,562	0 4 9	70,349	67,732·367	263,461 14 6	2 9 9½	128,910 6 5
Champion Reef	Oct., 1894, to Sept., 1895	49,705	65,871	1 6 12	13,385	3,249	0 4 20	69,120	68,001·266	264,459 14 4	2 9 4¼	139,393 13 4
Averages and totals ...		196,754	219,906	1 2 6	134,767	27,974	0 4 3	247,879	—	942,912 4 4	2 3 8½	486,044 9 1

* Quartz. † Gangue. ‡ Amalgamation. § Cyanide.

TABLE V.—ANALYSIS OF MINING AND MILLING COSTS OF THE MYSORE AND NUNDYDROOG COMPANIES IN 1892 AND 1895.

MINE COSTS PER TON OF ORE TREATED.

	Mysore.						Nundydroog.					
	1892.			1895.			1892.			1895.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
European labour ...	0	3	4·87	0	2	3·44	0	2	8·48	0	1	3·91
Native ,, ...	0	5	11·39	0	6	9·10	0	11	2·55	0	10	9·24
Fuel	0	7	8·42	0	6	11·56	0	6	6·72	0	5	10·19
Explosives	0	4	8·58	0	2	5·72	0	5	10·60	0	3	2·47
Timber...	0	0	8·94	0	1	1·09	0	1	5·84	0	0	8·11
Candles	0	0	7·98	0	0	6·78	0	0	11·01	0	0	10·40
Steel and iron ...	0	0	4·20	0	0	2·62	0	0	4·81	0	0	2·98
Oil and tallow ...	0	0	3·03	0	0	2·29	0	0	5·95	0	0	8·21
General stores ...	0	0	10·36	0	0	7·18	0	0	9·57	0	0	8·31
	£1	4	7¾	£1	1	1¾	£1	10	5½	£1	4	3¾

MILL COSTS PER TON OF ORE TREATED.

	Mysore.				Nundydroog.			
	1892.		1895.		1892.		1895.	
	s.	d.	s.	d.	s.	d.	s.	d.
European labour ...	1	3·34	0	8·22	0	10·32	0	10·12
Native ,, ...	2	3·06	1	0·67	1	4·01	1	3·89
Fuel	7	7·84	2	11·25	5	3·06	3	4·14
Shoes and dies	1	1·77	0	2·68	†0	0	†0	0
Mercury	0	5·22	0	1·24	0	3·81	0	1·43
Oil and tallow	0	3·12	0	1·24	0	2·25	0	1·11
Timber	0	1·80	0	1·00	†0	0	†0	0
General stores	0	9·86	0	6·20	0	6·88	0	7·93
	14	0	*5	8¼	8	6	6	4¾

* Does not include tailings treatment. To compare 1892 with 1895, 6s. 5¾d., the cost of amalgamation and cyanide treatment, must be added, which brings the total cost of milling and retreatment of tailings to 12s. 2¼d.

† Presumably included in "general stores."

TAILINGS COSTS BY AMALGAMATION PER TON OF TAILINGS TREATED.

	MYSORE. 1895. s. d.	NUNDYDROOG. 1895. s. d.
European labour	0 10·51	0 0
Native ,, ...	0 10·65	1 8·75
Fuel	3 3·64	3 6·94
Shoes and dies	1 8·68	*0 0
Mercury	0 2·25	0 1·63
Oil and tallow	0 1·56	0 2·27
Belting	0 0·25	*0 0
General stores	0 4·40	1 7·07
	7 5·94	7 2·66
	38,597 tons.	7,775 tons.

* Presumably included in "general stores."

TABLE VI.—THE YIELD OF GOLD OF THE DISTRICT SINCE THE BEGINNING OF 1889 IS AS FOLLOWS:—

	1889.	1890.	1891.	1892.	1893.	1894.	1895.
	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.
January ...	4,104	8,358	10,186	11,674	16,844	17,026	19,672
February ...	4,700	9,547	10,121	11,780	16,656	15,828	19,692
March ..	5,262	9,422	10,117	11,579	17,463	16,080	20,257
April	5,777	7,853	9,393	11,813	18,287	15,551	20,399
May	5,992	7,861	10,509	12,488	17,922	16,543	20,797
June	6,409	8,287	10,746	11,847	16,879	15,459	20,839
July	6,807	8,081	11,097	13,277	16,676	18,271	19,280
August ...	7,084	8,079	11,222	14,854	16,192	19,073	20,399
September ...	7,323	8,352	11,396	15,529	17,060	18,911	21,502
October ...	7,008	9,360	12,095	15,922	17,440	19,058	22,298
November ...	8,241	9,770	11,667	15,942	17,557	18,825	22,544
December ...	7,870	9,962	11,589	16,435	17,659	19,104	22,652
	76,577	104,932	130,138	163,140	206,635	209,729	250,331

§ TABLE VII.—SHOWING THE HEADS OF STAMPS ERECTED, THE TONS OF QUARTZ CRUSHED, OUNCES OF GOLD PRODUCED AND THEIR VALUE, BY THE COMPANIES AT WORK ON THE COLAR GOLD-FIELD OF MYSORE, FOR THE YEAR ENDED DECEMBER 31, 1895.‡

	Mysore. 90 Stamps.			Nundydroog. 40 Stamps.			Balaghat-Mysore. 25 Stamps.			Ooregum. 110 Stamps.			Champion Reefs. 80 Stamps, and 100 after June.			Mysore West and Mysore-Wynaad. (Tank Block.) 10 Stamps.			Mysore Reefs. (Kangundy.) 26 Stamps.			Nine Reefs. 40 Stamps.			Coromandel. No Stamps.			Yerrakonda. 10 Stamps			Total for Month
	Tons.	†Ozs.	£	Tons.	†Ozs.	£	Tons.	O.	£	Tons.	†Ozs.	£	Tons.	†Ozs.	£	Tons	Ozs.	£	Tons	Ozs.	£	Tons	Ozs.	£	T.	O.	£	T.	O.	£	£
Jan.	5,470	5,191	20,299	2,700	3,143	11,652	220	95	365	4,072	5,361	20,010	3,900	5,635	21,519	—	—	—	60	68	‡264	260	147	‡500	—	—	—	70	32	117	74,726
Feb.	5,140	4,953	19,821	2,580	3,058	11,342	150	81	299	4,004	5,382	20,051	3,800	5,636	21,961	200	77	‡299	64	80	332	303	146	519	500	217	844	142	52	193	75,661
Mar.	5,630	5,435	21,157	2,750	3,163	11,717	About	130	458	4,231	5,533	20,677	3,870	5,640	21,567	350	156	‡605	—	—	—	362	200	701	—	—	—	—	—	—	76,882
Apr.	5,520	5,478	21,220	2,700	3,160	11,784	—	—	—	4,066	5,608	20,977	3,900	5,645	21,562	350	160	‡620	120	128	487	360	220	766	—	—	—	?	?	126	77,542
May	5,200	5,453	21,273	2,775	3,178	11,886	—	—	—	4,321	6,046	22,648	3,900	5,651	21,581	395	264	‡1,023	—	—	—	371	205	738	—	—	—	—	—	—	79,149
June	4,875	5,056	19,762	2,750	3,201	11,846	—	—	—	4,540	6,012	22,570	4,490	5,910	22,598	410	291	‡1,128	186	236	899	350	133	412	—	—	—	—	—	—	79,215
July	3,809	3,620	14,275	2,800	3,236	11,904	—	—	—	4,826	6,039	22,674	4,700	6,608	29,956	400	306	‡1,186	—	—	—	*410	71	221	—	—	—	—	—	—	73,116
Aug.	4,440	4,844	18,940	2,800	3,267	11,974	—	—	—	4,629	6,052	22,951	4,750	6,068	23,172	195	104	‡393	—	—	—	310	64	‡248	—	—	—	—	—	—	77,678
Sept.	5,259	5,563	21,642	2,800	3,286	12,109	—	—	—	4,521	6,028	22,339	4,750	6,101	23,285	450	424	‡1,643	325	100	‡388	—	—	—	—	—	—	—	—	—	81,406
Oct.	5,020	5,699	22,120	2,820	3,295	12,232	—	—	—	4,826	6,036	22,659	4,850	6,204	23,968	465	951	‡3,686	350	113	‡438	—	—	—	—	—	—	—	—	—	85,103
Nov.	5,050	6,029	‡23,363	2,750	3,315	‡12,846	—	—	—	4,599	6,045	‡23,425	4,780	6,228	‡24,134	510	705	‡2,732	298	222	‡861	—	—	—	—	—	—	—	—	—	87,361
Dec.	5,250	6,123	‡23,727	2,750	3,321	‡12,869	—	—	—	4,785	6,207	‡24,053	4,855	6,537	‡24,169	550	538	‡2,085	317	116	‡450	277	110	‡427	—	—	—	—	—	—	87,780
Total	60,654	63,444	247,599	32,975	38,613	144,161	370	306	1,122	53,420	70,349	265,034	52,545	70,963	272,472	4,275	3,976	15,400	1,720	1,073	4,119	3,003	1,296	4,532	500	217	844	212	84	436	—

§ *Mining World and Engineering Record*, January 25th, 1896, pages 149 and 150. † The ounces in this column includes total yield from all sources—crushing, treatment of tailings, cyanide process, etc. ‡ The value is estimated at £3⅛ per ounce. * 130 tons of this only was quartz, the remainder country rock.

* TABLE VIII.—SHOWING THE VALUE OF THE GOLD PRODUCED FROM QUARTZ CRUSHINGS BY THE MINING COMPANIES AT WORK ON THE COLAR GOLD-FIELD OF MYSORE, FROM 1884 TO 1895.

Gold-Mining Companies.	VALUE OF GOLD PRODUCED.												Value of Gold Produced from June, 1884, to Dec. 31, 1895.	Tons of Quartz Crushed from June, 1884, to Dec. 31, 1895.
	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.		
	£	£	£	£	£	£	£	£	£	£	£	£	£	Tons.
Mysore ..	4,431	23,987	62,520	50,826	73,972	193,152	229,961	260,069	249,393	254,205	202,302	247,599	1,852,417	369,982
Ooregum ...	—	—	—	—	15,246	62,503	104,041	132,974	202,887	280,970	256,785	264,934	1,320,340	198,204
Nundydroog ...	—	—	—	5,737	26,487	22,947	58,906	89,345	118,026	103,558	110,784	144 161	679,951	146,246
Mysore Reefs	—	—	—	—	—	542	812	730	—	—	1,027	4,119	7,230	4,435
Nine Reefs ...	—	—	—	551	3,071	5,273	868	—	—	—	—	4,532	14,295	10,876
Kempinkote ...	—	—	—	1,682	4,139	5,714	5,242	—	—	—	—	—	16,777	14,285
Mysore West	—	—	—	—	—	—	—	—	—	—	1,039	15,400	16,439	4,538
Balagâht Mysore ...	—	—	—	682	10,538	13,782	13,821	20,282	27,129	27,830	21,907	1,122	137,093	21,817
Mysore Wynaad ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gold-fields of Mysore ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Yerraconda ...	—	—	—	—	380	233	—	—	—	—	—	436	1,049	737
Colar Central	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Champion Reef	—	—	—	—	—	—	—	—	25,711	119,662	204,441	272,472	622,286	117,759
Coromandel ...	—	—	—	—	—	—	—	—	—	—	—	844	844	500
Oriental ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total ...	4,431	23,987	62,520	59,478	133,833	304,146	413,651	503,400	623,146	786,225	798,285	955,619	4,668,721	889,379

* *Mining World and Engineering Record*, January 25th, 1896, pages 149 and 150.

TABLE IX.—RAINFALL AT COLAR DURING 1895.

	Inches.		Inches.
January...	None	August	4·56
February	,,	September	10·04
March	,,	October	6·87
April	2·24	November	0·42
May	2·84	December	2·23
June	2·01		
July	2·09	Total	33·30

The following paper by Mr. Horace F. Brown on "Mechanical Roasting of Ores" was taken as read :—

MECHANICAL ROASTING OF ORES.

By HORACE F. BROWN, Chicago, Illinois, U.S.A.

The rapid depletion of surface or oxidized ore, together with improved processes for treating sulphide and other refractory ores, has made the question of economical oxidization one of great metallurgical importance.

There have been numerous devices for mechanical rabbling brought into use within the last decade, all possessing merit, but the evolution of the reverberatory type of calciners seems to more nearly have solved the problem than any other.

Probably the first marked improvement in the line of mechanically-stirred reverberatory calciners, was made by Mr. O'Harra, who placed drums at each end of the furnace, and by means of a chain passing over the drums, dragged a triangular frame over the ore-bed, attached to which were rabbling-points. While somewhat crude and faulty in construction, it was the foundation upon which all the improvements in reverberatory calciners have been built.

The drawbacks in the O'Harra calciners were first, the excessive wear of the rabbling-points that dragged along the brick-hearth; and second, the deterioration of the chain which passed through the centre of the hearth and was exposed to the excessive heat, as well as to the attrition of the ore through which it was drawn. So serious were these defects that the constant breakage and delays neutralized the advantages, and but few furnaces came into use.

In 1890, Mr. Chas. M. Allen, of Butte, Montana, U.S.A., placed cast-iron tracks through the centre, which projected high enough to form a groove, virtually dividing the hearth into two parts, with the groove or channel-way between.

The triangular frame carrying the rabbling-points was mounted on wheels, and at close intervals small wheeled carriages were attached to the chain. These carriages supported the chain directly over the central channel, entirely obviating the wear by attrition on the ore. The channel was kept clear by scrapers that were attached to the carriers.

In 1891, the writer designed the slotted wall construction for protecting the mechanism of a mechanical furnace, and it is the purpose of this paper to describe this construction.

In cross-section, the Brown system of furnaces are all virtually the same—the roasting-hearth being cut off from the exterior compartments by a slotted wall, through which an arm, carrying rabble-points, is extended over the ore-bed (Fig. 1, Plate XX.).

In the exterior compartment, tracks are laid, and the necessary guide wheels for carrying the operating cable, while only the arm of the stirring-carriage is exposed to the direct heat and fumes of the furnace.

In general plan, the Brown furnace system is similar to an ordinary street cable-railway, the operating mechanism being an ordinary simple cable drive, and each stirring-carriage representing a grip-car.

There is no arbitrary shape of ground-plan, as the general shape of the furnace can be varied to suit local conditions. For some reasons, the writer prefers a circular plan, as shown in the horse-shoe type. In this construction the hearth is formed into a true circle, the roasting-hearth comprising about five-sixths, and the space between the adjacent ends, one-sixth of the entire circle.

The driving mechanism is situated in this open space, and consists of a grip-wheel, with guide and tension-wheels arranged in the simplest form. The cable passes around in the exterior compartment next to the inner wall of the structure, and is supported by guide-wheels in the same manner as a railway cable around a curve.

The rabbling carriages consist of an L-shaped frame, one side of which is fitted with double flanged wheels for running on a small T-rail in the exterior compartment, and the other side extending across the width of the furnace, its opposite end being supported in the outer exterior chamber by a flat-tread wheel running on a smooth rail.

On this laterally-projecting arm the rabble-points are secured. As now constructed, the rabbles consist of an arm of cast-steel, terminating with a cast-iron wearing-point. The rabbles stand at such an inclination as to cause them to lift the ore and to turn it each way, leaving the bed a succession of ridges or furrows.

The entire wear of the cast-iron shoe is on the bottom, so that it presents a pointed, cutting edge at all times to the ore, and the arm is so secured to the carriage that it can be lowered as fast as the shoe is worn, keeping the point always cutting on the same plane. This prevents the forming of accretions over the hearth.

The hearth is constructed so that there is a space of about 2 inches between the rabbles and the brick-bottom. This space is filled with crushed oxide of iron, limestone-rock, or other neutral material, which forms the real working-bottom of the furnace.

Should any accretions form on account of inattention, the rabble-points can be lowered a trifle, one at a time, just sufficient to cut down into the loose material, and all accretions are removed without the necessity of barring.

To guard against any possible contingency that might arise in roasting lead sulphides, or rich lead and copper mattes, the furnace is so constructed that every part is accessible from either side.

The side walls are built to a level with the hearth, usually about 3 feet, when heavy cast-iron door-frames are placed along each wall, about 4 feet apart. On these frames heavy channel-beams (9 inches) are placed and secured by the buck-staves. The arch is sprung directly from these channel-beams, and is supported entirely by the ironwork. The space between the door-frames is filled in with a thin wall, just enough to exclude the outside air and retain the heat.

The tiles that form the lower half of the slotted wall are constructed and set in the hearth, so that they can be lifted out at will and replaced without cooling down the furnace. This can be done through the doorways, but should it be necessary the brick can be removed between the door-frames, leaving the furnace a skeleton construction, perfectly open all around.

Since the adoption of the sectional rabbling-points, the writer has had no occasion to bar the hearth, as by keeping the points down to the same working-plane no accretions form that cannot be cut out in the rabbling without delay or trouble.

In operation, the carriages run alternately, one carriage being all the time at rest in the open space between the two ends of the hearth, while the other is making the circuit. When the forward moving carriage comes in contact with the carriage at rest it is pushed forward until the grip-lever comes in contact with a fixed stop, and as it is advanced the lever is forced down, gripping the cable the same as in cable railway practice.

Immediately after the forward carriage is gripped to the cable, the rear or heated carriage is automatically released, and comes to rest, being rapidly cooled while the circuit is being made by the other. In this manner the carriages are alternately cooled, and are never injuriously affected by the heat of the furnace.

The cable is running all the time, one-third of its length being in the open air, and it is never heated so as to affect it in any manner. The life of the cable is about eight months, but the writer has had cables running over a year on two occasions. He has attained the best results

with Lang laid cables of annealed steel, seven wires to the strand, the centre made with nineteen iron wires, to give greater flexibility.

The ore is fed to the furnace by an automatic feeder, which delivers a weighed amount at the passage of each stirrer. The ore is delivered to the hearth entirely outside, so that any dust made in feeding fine dry material is settled before coming in contact with the draught of the furnace.

The ore is led to the hearth by a canvas tube, 12 inches wide between the parallel walls, and 8 feet, or the width of the hearth, in length. The lower end of the tube is sheet metal, which is attached, by means of small cables, to a rocking shaft, which is so arranged that a projecting lever striking the moving carriage, causes it to partially revolve, lifting the tube above the line of the carriage. As soon as the carriage passes this point, the lever is released and the tube drops back to position, the sheet-metal bottom being embedded in the ore so as to make an air-tight joint.

The descending arm, which supports the tube, comes in contact with a small lever, which starts the feed-mechanism into operation. This mechanism consists of a ratchet-wheel and pawl. The pawl is worked by a continuously revolving shaft, and the ratchet-wheel is secured to a long pocket roller, that closes the bottom of the feed-hopper and extends entirely across the hearth.

As the pocket-wheel revolves, the ore is forced out and passes to the hearth through the canvas tube. The amount fed in each time is regulated by adjustable stops on the ratchet-wheel, which are set so as to come in contact with a weighted lever, the movement of which throws the pawl out of gear, and holds it suspended until again put into gear by the passing stirring carriage. By these means, the amount fed in is perfectly regulated, and with fine, dry material the operation is almost dustless.

Once on the hearth, the action of the stirrer is so perfectly gentle that no mechanical dust is raised, and but for the decrepitation of the iron-sulphide there would not be a perceptible amount of dust passing to the dust-chambers.

The forward travel of the ore depends entirely on the tonnage being worked, varying from 6½ to 35 feet per hour. The frequency of the rabbling is regulated to suit the material, and is varied from once each minute to once in three minutes, as experience dictates. The frequency of the rabbling is gained, first, by the speed of the carriage, and, second, by the number in the circuit.

The heat is introduced to the hearth through openings in the roof, and is regulated to suit the ore. From the inlet, or feed-end of the furnace, to the first fire-box is about 60 feet, except where the furnace is designed for roasting zinc blende. Towards the finish, or discharge end of the furnace, the fire-boxes are from 35 to 40 feet apart, the heaviest firing being done at the last fire-box, where there remains sulphate compounds to be broken up.

With this arrangement of the fire-boxes, the ore enters at the coolest part of the furnace, and is gradually drawn towards the hotter portion, the heat increasing to the last. A heavy sulphide ore will ignite within 15 feet of the feed-door, or within an hour after being fed in, while ores low in sulphur do not reach an oxidizing heat under 2 or 2½ hours.

This matter is entirely under control, and must be regulated to suit the ores under treatment, requiring judgment and a fair amount of skill on the part of the fireman to produce the best results. This matter of skill and good judgment is the keynote to success in using mechanical roasters, as well as in other branches of metallurgical work. There is nothing new in the chemistry of roasting in connexion with a mechanical roaster; but there is a more perfect application of heat and oxygen, and a more uniform exposure of every particle to the oxidizing agencies, and, in consequence, more rapid and perfect results are obtained, and the more skilled the operator is in the chemical laws governing his work the more perfect and satisfactory will be the results.

The advantages claimed for the Brown system of roasting furnaces are:—

(1) Flexibility and capability of adaptation to meet local requirements and metallurgical conditions;

(2) Simplicity of construction, both as to the brickwork and mechanical details of the stirring mechanism; and

(3) Absolute protection of the stirring mechanism from the heat and furnace fumes.

As to the first claim, it will be readily understood that no arbitrary shape is essential in the ground-plan of the Brown furnaces.

One of these furnaces (Fig. 2, Plate XX.), built for the Bi-Metallic Mining Co., Philipsburg, Montana, U.S.A., occupies the old cooling-floor of their mill. The roasting-hearth, designed for roasting and chloridizing silver-ores, extends along the cooling-floor in a straight line for 220 feet. From the end of the roasting-hearth a sheet-metal hearth extends in a half-circle, on a radius of about 20 feet in internal diameter, and then along over the system of leaching-tanks, parallel to the roasting-hearth, the tracks extending around to complete the circuit.

The ore is carried through the roasting and chloridizing-hearth, and around over the cooling-hearth, by the same mechanism, and automatically discharged into the leaching-tanks, thus avoiding all manual labour, and entirely obviating the mechanical dust incident to the usual cooling-floor practice.

A furnace erected for the Golden Reward Mining Company, at Deadwood, South Dakota, U.S.A., is built elliptical in plan, the available space in connexion with their mill somewhat governing the shape. The roasting-hearth is U-shaped, the extension cooling-hearth and open tracks completing the circuit (Fig. 3, Plate XXI.).

In this furnace the roasting-hearth is 8 feet wide by 180 feet long, measuring on a centre line, giving 1,440 square feet of roasting area. The material calcined is a close-grained, hard, blue quartz, carrying from 3 to 8 per cent. of sulphur in arsenical iron pyrites. The ore is crushed dry to thirty meshes, and is roasted sweet for barrel-chlorination.

Three rabbling-carriages are used for roasting 60 tons per day, the feed being set to charge in 127 lbs. with the passage of each carriage. There are two carriages moving, and one all the time at rest in the open space. At the usual speed, a carriage makes the complete circuit in 2 minutes 50½ seconds, which gives the ore-bed a thorough rabbling every 85 seconds. The forward travel of the ore is about 22½ feet per hour, or eight hours for the full length of the hearth. At 120 feet, or about five hours, when feeding at the rate of 60 tons, the ore is perfectly oxidized, showing the merest trace of arsenic, and less than 0·30 of sulphur.

When four carriages are in use, the feed and forward travel are increased by 50 per cent., making an average of over 90 tons a day. This charge is about five hours making the circuit, but is perfectly oxidized in 4½ hours, or at a point about 155 feet from the feed-door. This shows a duty of 1 ton for each 13 square feet of hearth-area, or a safe capacity of 100 tons per day, for a furnace having a roasting-hearth 180 feet long by 8 feet wide.

The extension cooling-hearth of the Golden Reward furnace as built, is 68 feet long, but was originally designed to be 90 feet, or one-half of the length of the roasting-hearth. To save an abnormally high retaining-wall, where the grading cut into a point of the hill, the cooling-hearth was shortened 20 feet in length.

The cooling is accomplished by radiation, no water being used except a fine spray at the point of discharge to the elevator, to prevent dust. The shortening of the cooling-hearth was an error, as when run to 90 tons and upwards, the calcined ore is not cooled much below 200 degs.

Fahr. The fuel used is pine-wood, although coal is more commonly used, owing to the cost being less.

The work of oxidizing, cooling, and conveying the calcined ore to the chlorination-barrels is as follows per day of twenty-four hours :—

	Dollars.	Dollars.
2 Firemen	at 2·50 ...	5·00
6 Cords of wood	at 3·25 ...	19·50
Power, oil, and repairs (estimated) ...	— ...	2·50
Interest on plant, etc.	— ...	2·00
		$29·00

For some time, but 48 tons were fed in, and it required the same amount of fuel to keep up an oxidizing heat, as when 60 tons were being worked, and no increase of fuel was found necessary to perfectly oxidize 90 tons per day. In this case there is not enough sulphur to assist in any appreciable degree in keeping up the heat.

In roasting zinc blende, a much higher heat is carried, especially towards the finish, when a high degree is required to break up the sulphate compounds. At the Collinsville Zinc Works, Collinsville, Illinois, U.S.A., two of the standard horse-shoe type of furnaces are roasting heavy zinc sulphide. From a record of two years' steady work the company have furnished the following data:—Roasting-hearth, 135 feet long by 8 feet wide, making a total of 1,080 square feet hearth area. The ore is crushed to an 8 meshes size, and averages 58 per cent. of zinc, and 28 per cent. of sulphur. An average of 20,000 lbs. of calcined material is gained, roasted down to 0·85 of sulphur.

Labour per 24 hours, two men at 2½ dollars	$5·00
8 tons fine slack coal, containing 33 per cent. of ash...	2·00
Power, oil, and repairs	1·00
	$8·00

or 0·80 cent per ton for the finished product. The coal used is the refuse slack from an adjacent coal-mine, and costs nothing beyond switching charges.

The labour expense, as compared to hand-roasting, is as 1 to 6. In the hand-kiln, formerly used for roasting, there was a large loss by volatilization, owing to the excessive heat on the lower hearth, but in mechanical roasting there is no perceptible loss, as the rabbling is so frequent that the ore does not get burned. The best working by hand rabbling brought the sulphur down to an average of 1½ per cent. The increased amount of spelter produced from the ore calcined in the

mechanical roaster, owing to more uniform and perfect roasting, and the diminutive loss by volatilization, more than pays for the total cost, so that by comparison with hand rabbling it costs less than nothing in the mechanical furnace.

For small plants where but 10 to 12 tons of concentrates are to be worked, the writer builds what, for convenience, he calls a parallel furnace. In this furnace (Fig. 4, Plate XXI.) the roasting-hearth is straight, about 60 feet in length, and the extension cooling-hearth and tracks are connected by curved ends, and come back parallel to the brickwork. This makes a very compact, cheap construction, and is especially adapted for small plants.

At the works of the Consolidated Kansas City Smelting Company, Argentine, Kansas, U.S.A., one of the standard horse-shoe furnaces is in use for the sulphate-oxide calcination of high-grade copper-lead matte, for the Hunt-Douglass process of copper extraction. This material is so fusible that in hand-roasting it agglomerated together to such an extent, that it was necessary to re-grind and re-roast; but in the horse-shoe furnace, the required result is obtained at a single roast, at a cost of 0·61 cent as against 3·75 dollars by hand-rabbling, saving the loss of re-grinding.

In point of cost, the Brown system of furnaces cost about one-half as much per ton of capacity, as other mechanical roasters. An elliptical furnace with a roasting-hearth 180 feet long costs in the mining sections of the United States from 9,500 to 11,500 dollars, depending on proximity to the railroad, and local price of labour and material. The standard horse-shoe furnace with a hearth 135 feet long, costs from 6,500 to 7,500 dollars, according to location, and the parallel furnace 3,200 to 4,000 dollars.

Rates of freight on machinery and fire-brick vary so much, as well as local prices of common brick and other material, that it is impossible to give anything but an approximate cost, except in a specified location.

The writer appends an itemized list of materials required for the erection of the three types of Brown roasters described in the foregoing:—

The Federated Institution of Mining Engineers.
Transactions, 1895-96.

To illustrate Mr. Horace F. Brown's Paper on "Mechanical Roasting of Ores."

VOL. XI., PLATE XX.

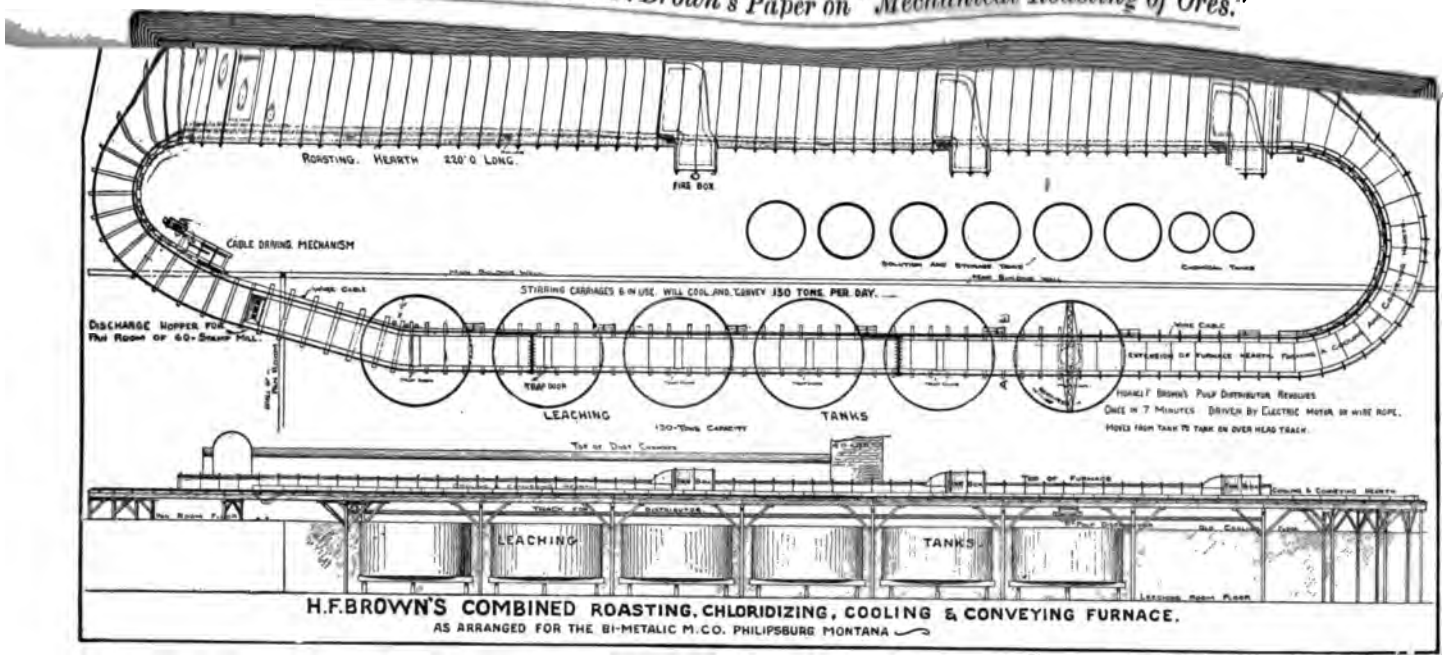

ROASTING HEARTH 220'0 LONG.
FIRE BOX
CABLE DRIVING MECHANISM
STIRRING CARRIAGES 6 IN USE. WILL COOL AND CONVEY 150 TONS PER DAY.
DISCHARGE HOPPER FOR THE ROOM OF 60-STAMP MILL.
TRAP DOOR
LEACHING
TANKS
150-TONS CAPACITY
HORACE F BROWN'S PULP DISTRIBUTOR REVOLVES ONCE IN 7 MINUTES DRIVEN BY ELECTRIC MOTOR OR WIRE ROPE. MOVES FROM TANK TO TANK ON OVER HEAD TRACK.
LEACHING
TANKS
H.F.BROWN'S COMBINED ROASTING, CHLORIDIZING, COOLING & CONVEYING FURNACE.
AS ARRANGED FOR THE BI-METALIC M.CO. PHILIPSBURG MONTANA

FIGURE 2.

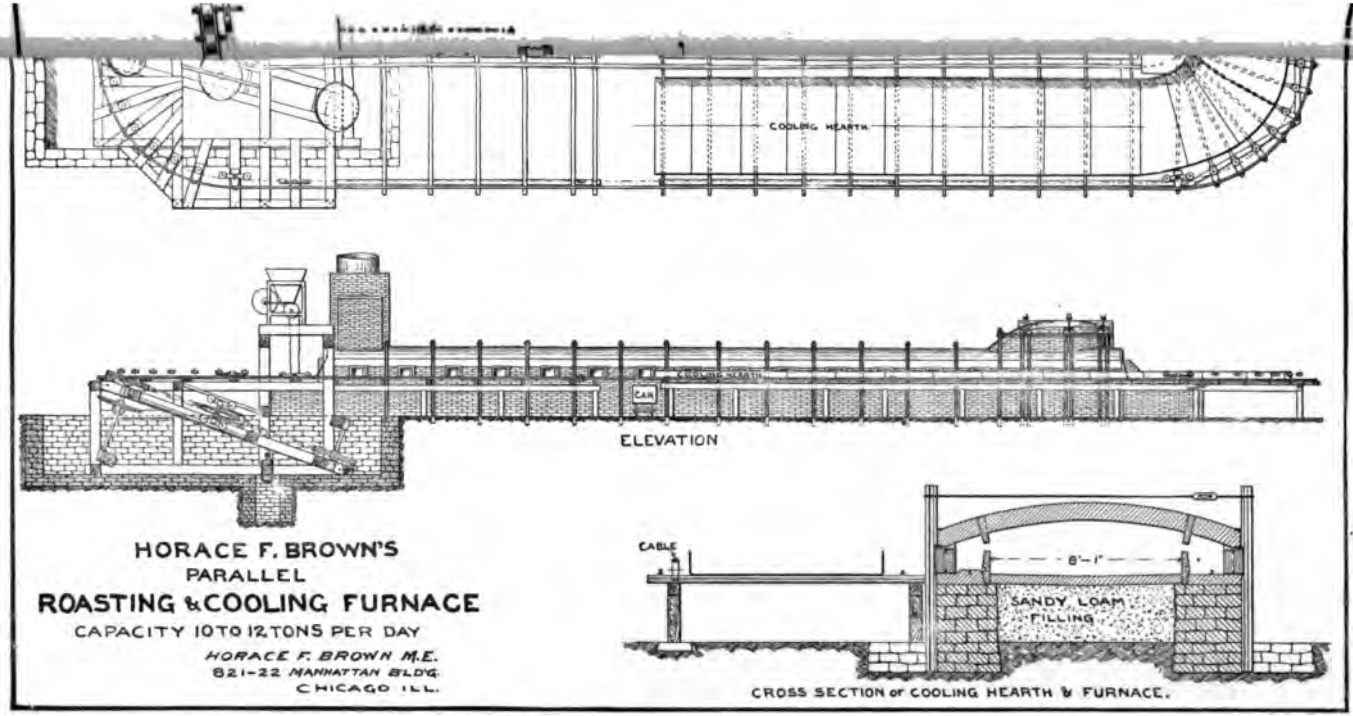

COOLING HEARTH
CAR
ELEVATION
HORACE F. BROWN'S
PARALLEL
ROASTING & COOLING FURNACE
CAPACITY 10 TO 12 TONS PER DAY
HORACE F. BROWN M.E.
821-22 MANHATTAN BLD'G.
CHICAGO ILL.
CABLE
8'-1"
SANDY LOAM
FILLING
CROSS SECTION of COOLING HEARTH & FURNACE.

FIGURE 4.

Description. Drawings	Standard Horse-shoe Furnace. Fig. 1, Plate XX.	Elliptical Furnace. Fig. 3, Plate XXI.	Parallel Furnace. Fig. 4, Plate XXI.
Roasting-hearth—			
Dimensions	135 ft. long by 8 ft. wide	180 ft. long by 8 ft. wide	60 ft. long by 8 ft. wide
Capacity, per day	25 to 50 tons	50 to 100 tons	10 to 20 tons
Red bricks	60,000	90,000	30,000
Square fire-bricks	4,500	8,000	2,000
Wedge-bricks	600	—	—
Perches of stone	150	400	50
Fireclay tiling, tons	12½	16	5½
Fireclay, tons	8	12	2
Machinists' work, days	10	20	20
Carpenters' ,, ,,	10	10	10
Masons' ,, ,,	175	250	75
Labourers' ,, ,,	175	250	100
Lime, bushels	180	250	80
Cement, barrels	15	25	8
Sand, cubic yards	90	100	40
Timber, board measure, for machinery frame-work, feet	3,000	4,000	2,500
Buck-staves, usually old railway rails, lbs.	20,000	24,000	—
Weight of complete ironwork, exclusive of buck-staves, lbs.	35,000	50,000	25,000*
Weight of 90 feet cooling-hearth and material, lbs.	—	13,500	—
Cost of complete ironwork, exclusive of buck-staves	$3,500 or £700	$4,500 or £900	$2,500 or £500*
Stack of sheet-metal on brick-base—			
Dimensions	42 ins. by 80 ft.	48 ins. by 85 ft.	30 ins. by 60 ft.
Bricks for base	4,500	5,000	3,000
Perches of stone for base	10	15	6
Masons' work, days	8	10	5
Labourers' ,, ,,	8	10	5
Lime, bushels	15	20	10
Sand, cubic yards	8	10	5
Weight of stack, including base-plates, lbs., about	5,200	6,500	3,000

* Including buck-staves.

The following "Geological Description of the Gold-mines of the Transvaal," etc., by Prof. L. de Launay, was taken as read :—

GEOLOGICAL DESCRIPTION OF THE GOLD-MINES OF THE TRANSVAAL (WITWATERSRAND, HEIDELBERG, AND KLERKSDORP DISTRICTS).*

By L. DE LAUNAY, Mining Engineer, and Professor in the School of Mines, Paris.

The present paper is based on a work recently published in the French language,† of which the author has already printed considerable portions in the *Annales des Mines*, the official organ of the French Ministry of Public Works. It is the outcome of detailed observations made on the spot, at Johannesburg, in the months of July, August, and September, 1895, and its chief object is to set forth the result of his personal study of the gold-bearing deposits of the Transvaal.

As the title of the present paper indicates, its scope will be restricted to the gold-fields of the Witwatersrand, of Heidelberg, and of Klerksdorp, leaving out of account the districts of De Kaap (Barberton), Komati, Lydenburg, Murchison Range, Zoutpansberg, etc., in the Transvaal, as well as the newly discovered fields of Zululand, Mashonaland, and Bechuanaland. The author's purpose is to speak only of what he has himself seen, and as his stay in South Africa was a short one, he has preferred to concentrate his attention on one specific subject, instead of frittering away his efforts in different directions.

The gold-fields of the Witwatersrand, of Heidelberg, and Klerksdorp, which will now be described, present this characteristic feature, that instead of containing veins of gold-quartz analogous to those of California and Australia (or, nearer at hand, those of Lydenburg, Barberton, and Mashonaland), they are formed of auriferous conglomerates known as "bankets," most probably of a sedimentary origin—so far as can be seen from the workings, at any rate. All three belong to one and the same geological formation, which the writer, had he not feared the possibility of being misunderstood, would have been inclined to call "the Witwaters-

* Translated by L. L. Belinfante, B.Sc.

† *Les Mines d'Or du Transvaal* (The Gold Mines of the Transvaal) 8vo., 530 pages, with numerous figures in the text and 11 plates. Published by Baudry & Co., 19, Rue des Saints Pères, Paris. This book deals also with the working of the mines, the metallurgical treatment of the ores, the financial constitution of the companies, etc.

rand synclinal." This formation has, up to the present, been observed only in these three gold-fields, and thus it is that in studying them the subject will be dealt with as fully as the now available knowledge will allow—although there is no theoretical reason for supposing that the area of the formation is so limited in extent.

In this paper it is proposed to treat, firstly, of the general geology of the area, including the old auriferous beds and the Carboniferous deposits of the Karoo; secondly, of the gold deposits, made up, as we all know, of conglomerates, with quartz-pebbles, or less commonly, interbedded with quartzites (the so-called "reefs"); thirdly, the gold ores and the details of their structure; fourthly, the grade of the ore and its variations; fifthly and lastly, the origin and mode of formation of the deposits and ores.

A.—General Geology of the Area.

The most striking feature of South African geology, taken as a whole, is the existence, overlying a basement of gneiss and granite, of ancient formations—Silurian, Devonian, and Carboniferous, much folded and eroded. These are unconformably overlain by the great horizontal plateaux of the Karoo—comprising thousands of feet of strata, wherein not a single marine fossil occurs, ranging from the Permian, perhaps even from the Upper Carboniferous, to the Infra-Lias.

The gold-bearing conglomerates are found in the ancient folded rocks, while the coal-beds, by the help of which it is possible to work the mines, occur in their immediate neighbourhood, in the overlying Karoo formation.

1. *Granite, Gneiss, and Primary Auriferous Series.*

The study of this series will be commenced by means of two sections running north and south, which the author himself took near Johannesburg. These will be, first of all, described in some detail without suggesting any hypothesis as to the age of the rocks. As will be seen, one finds, going from north to south, granite and gneiss, then quartzite, with shales and ferruginous fine-grained sandstones, followed by another series of quartzites, containing the various gold-bearing bands from the main reef in the north to the black reef in the south, dolomitic limestones, and yet another series of fine-grained quartzites (Gatsrand Series) forming the basin of a synclinal, after which the same beds crop out in the reverse order.

This description of sections, which the reader may at times find rather dry, will furnish a basis for the proposition and discussion of an

hypothesis, interesting equally by reason of its theoretical and practical consequences, namely, the arrangement of the gold-bearing conglomerates in the form of a synclinal striking generally north-east and south-west, which may be geologically extended a long distance in both directions (Fig. 5, Plate XXII.).

Figs. 1 to 3, Plate XXII., show that one need not go much more than 1½ miles north of Johannesburg to find a great mass of granite and gneiss some miles broad; it extends from that point, striking east and west, parallel with all the folds of the area. These plutonic rocks appear, in accordance with a rule which seems to hold good in all countries, and which the author has found especially confirmed in the French district of Bourbonnais, in an anticlinal arch of folded ancient sedimentaries.

Unfortunately, as so often happens with the older rocks of this area, the granite is largely masked by superficial drifts, in such wise that the observer is unable to study its contact with the stratified rocks, and thus misses the opportunity of an interesting indication of its age in relation to the last-named. The granite is practically identical with that of the Central Plateau of France, and veins of granulite occur in it. Near Houten Estate, a fine-grained granulite was found, with greenish micas and iron pyrites, accompanied by pyritous quartz, analogous to the granulite which often occurs in stanniferous veins, and which sometimes too is associated with gold.* Dykes of greenstone are also observed (6 and 7),† and considerable quartz-veins, striking roughly north and south—one of which follows for a long distance westward the old road from Potchefstroom to Pretoria. This last vein runs along the line of an old fault, for, near a farm, on the northern boundary of the accompanying map, a portion of the older shale series reappears at the contact.

After traversing the granite from north to south (the rock occupies a broad, gently undulating tableland which slopes to the north, towards Pretoria) one finds a long, very characteristic ridge, rising sharply some 300 feet. This ridge is made up of fine-grained quartzites which dip about 50 degs. southward, that is, away from the granite.

These quartzites which are very hard rocks, having resisted erosion while the subjacent granite crumbled away, present broken and jagged outlines whose picturesque effect is in striking contrast with the monotony

* Sample No. 1,450, 3 in the collection of metalliferous deposits at the Paris School of Mines. Compare with this the berezite from Berezovsk in the Urals, No. 1,675, 3. All other references thus marked (1,450, 3) in the following pages apply also to this collection.

† These figures, reproduced on the map (Fig. 2, Plate XXII.), correspond to samples of collection 1,450.

of the granitic hummocks. At the same time as the rocks change, so does the water-system of the region. Thus, while in every depression of the granite (even during the dry winter season) little streamlets well forth, giving rise to marshy meadows, and watering deposits of humus which will one day richly repay the agriculturist who sees fit to work them, so soon as one reaches the quartzite-area, a desert-like sterility and aridity meet the eye. From this point as far as the bottom of the synclinal of Springs and Potchefstroom (Figs. 4 and 5, Plate XXII.) the beds dip continually southward, and the sandstones, being more or less fissured and permeable, drain off all the water, carrying it down far below the surface towards the Vaal river. The result is that springs are not to be found,* and this fact has some importance as bearing on the working of mines to the deep.

This zone of quartzites may be reckoned as about 1,600 feet thick (Figs. 1 and 3, Plate XXII.). Next comes, on the two flanks of a small valley, above which rises to the south Hospital Hill (the uppermost part of Johannesburg), a highly characteristic and important series of shales and ferruginous fine-grained sandstones, all permeated with magnetite, and therefore causing a deviation of the compass-needle, with a few interbedded quartzites similar to those above described.

Section U V (Fig. 2, Plate XXII.) was taken more to the eastward, near the farm of Doornfontein, across the Geldenhuis Valley. In this section, which the writer was able to follow farther south than the first one, the same characteristic features are shown. In the north are the white quartzites in contact with the granite, followed by a shaly and ferruginous series, then again by quartzites. Only the thicknesses vary—but that considerably—from one section to the next, by reason of a phenomenon which we shall notice along the whole length of the Rand when we come to study more especially the Main Reef Series. In the above section U V, however, in the midst of the later quartzites, and before coming to the main reef, one meets with a zone of slightly auriferous conglomerates (44 to 50), succeeded by another series of ferruginous shales, which, perhaps, in the first section are masked by the town of Johannesburg itself.

* The numerous *Fonteins* noticeable in the vast majority of names of farms in the Transvaal, and which (for the greater embarrassment of those who consult maps) are tacked on over and over again to the same names as, *e.g.*, Elandsfontein, Doornfontein, Modderfontein, Rietfontein, Randfontein, etc., hardly ever correspond to natural springs—as one might perhaps infer—but apply to merely artificial ponds or reservoirs, similar to those which are now everywhere built by the mining companies.

It will be well now to recur to certain points in the two sections, in order to define the part played in the general structure of the country by the different geological constituents of this first series of rocks lying below the auriferous conglomerates of the main reef.

First of all, the granite and gneiss extend a long way east and west from the point where we have noted them north of Johannesburg. Mr. Draper has also observed them at Vredefort and Halfway House. Westward, the accompanying map (Fig. 5, Plate XXII.) shows, following Mr. Goldmann's work, a great dyke of granite running north and south, which seems here to have uptilted the conglomerate series, and is, consequently, of a later date than that series (unless we have here a massif, which is practically a fault-block or *horst*). Finally, to the south, on the other side of a great synclinal of ancient strata, upon which, so far, all the gold workings have been concentrated, the same crystalline rocks are found 12 miles or so east of Heidelberg, and farther westward towards the Vaal, south of Venterskoon.

Above the granite, just as in the preceding sections, comes a series of clay-slates and magnetite-bearing sandstones, with interbedded quartzites. It is possible that these do not constitute a formation geologically distinct from the conformably overlying sandstones, but they are both of theoretical and practical importance.

A curious feature of this series is the banding of red quartz and magnetite (accompanied, according to Mr. Goldmann, by titanite). The ferruginous band was quite characteristic enough to serve as an indicator, in the early days of the gold-workings, to those prospectors who were looking for the main reef which was always the roof of it. The band has been followed to the west by Mr. Sawyer up to Krugersdorp, beyond Hartebeestfontein, and as far as Blaauwbank, where it disappears beneath the Black Reef Series. The whole slate series to which it belongs, already described by Messrs. Draper and Sawyer under the name of the Clay-slate Series,* was again noted by them at Zuikerbosch river, where it cuts the valley at right angles, and south of Ousthorn, where, according to these writers, the formation consists of black slates and quartzites.

Moreover, some 12 miles east of Heidelberg, Mr. Draper has noted below the gold-bearing conglomerates alternating beds of quartzite and slates, the latter often highly ferruginous. He particularly lays stress on the occurrence at this point of a band formed of thin stratulæ of magnetite and saccharoidal quartz, similar to the band described above.

* *Proceedings of the Geological Society of South Africa*, June 1st, 1895.

To sum up, it has been seen that over the whole area of the Witwatersrand, at the base of the ancient sedimentaries, between the granite and the gold-bearing conglomerates there intervenes a series of ferruginous shales alternating with quartzites identically the same as those that accompany the conglomerates.

An attempt, or rather several attempts have been made to trace these clay-slates and magnetite-grits over a much vaster area. Mr. Sawyer mentions them in Mashonaland, and Mr. Draper in Cape Colony, where clay-slates occur much as on the Witwatersrand, between the granite and the ancient quartzites and conglomerates of Table Mountain (analogous to those of Johannesburg). In the latter case, there are, perhaps, stratigraphical reasons to be urged in favour of the correlation. But, as a rule, it is well to treat with caution correlations bridging over such enormous distances. For that matter, we could point on the one hand to Brazil, and on the other to France, where exactly similar rocks occur, similarly overlain by conglomerates.

Certainly, if we could accept as proved the identity of the ferruginous shales of Hospital Hill and their overlying conglomerates with the analogous rocks of Table Mountain, we should arrive at highly interesting conclusions. And for this reason, that in Cape Colony, the above described rocks are immediately and conformably overlain by one of the very few fossiliferous horizons known in the older formations of South Africa—the micaceous shales of the Bokkeveld Series, with fossils of Upper Devonian age—*Homalonotus Herschelli*, *Spirifer antarcticus*, etc. This would confirm the Devonian age generally assigned—but so far without proofs—to the gold-bearing conglomerates of the Witwatersrand.

One of these days, it may well be that this hæmatite and magnetite series will have an importance of another kind, for it seems extremely probable that these iron oxides, so abundant at the outcrop, are the result of the decomposition of masses of pyrites, which form vast deposits deeper down. In fact, we are perhaps dealing with *chapeaux* or gossans of iron ore, analogous to those which are the indicators of all the great pyrites-deposits, as, for example, those of Huelva in Spain, already described by the present author. Moreover, as gold is in the Witwatersrand constantly associated with iron pyrites, there is no great improbability that workable gold would be discovered in some parts of these rocks, and we should then have an auriferous deposit, very comparable to those known to occur so frequently in Brazil in the form of gold-bearing

hæmatites.* The writer is, however, bound to admit that two assays made by him with samples of these magnetiferous grits yielded only traces of gold, a result which is scarcely encouraging in a country where so many duly recognized auriferous sites have still to be worked.

Following the section still southward, one comes, above this first series of rocks, upon a considerable mass of grits and auriferous conglomerates, which are some 24,600 feet (7,500 metres) in thickness. Like all the "primary strata" of the Witwatersrand this series has as yet revealed no trace of fossils, wherefore its age is still undetermined, and can only hypothetically be referred to the Upper Devonian (Old Red Sandstone). All the workings are opened in this formation. As it is proposed to describe the workings in detail on another page, a brief outline will suffice here.

In a general way, the rocks of this formation are almost entirely made up of quartzitic material (derived from quartz or quartzite) in the shape of fragments more or less minute, more or less rounded, embedded in a siliceous matrix. This matrix is sometimes pyritous. According to the size of the rolled fragments, we have fine or coarse-grained quartzites and conglomerates. In these, but more particularly in the conglomerates, at a large number of levels (over a total thickness of several thousand feet) traces of gold have been discovered, and in some of the conglomerates are worked the chief mines, of which a description will be supplied on a subsequent page.

From north to south, or, reckoning stratigraphically, from bottom to top, the conglomerate series includes the Rietfontein reef, or Du Preez reef; the Main Reef Group, made up of the north reef, now seldom worked, the main reef leader,† and the south reef; farther south come the Elsburg or De Paaz reef, the bird reef, and the monarch reef (unworked); the Kimberley or battery reef, on which some workings are still found; and, finally, the black reef, the conditions of deposition and mode of formation of which are quite distinct.‡

* Attention may be called especially to the resemblance between these magnetiferous sandstones and the sandstones with intercalated bands of auriferous pyrites, some samples of which are to be seen at the Paris School of Mines (1762, Rapazos mine, Brazil).

† A "leader" is, in a series of strata, as here in the main reef, a thin band of ore.

‡ To every separate fragment of a reef, particularly at the eastern and western extremities of the gold-field, where assimilation or correlation is more difficult, distinct names have been applied. These it seems unnecessary to reproduce here. It will suffice to note that the Bothas reef of the west appears to correspond to the Main Reef Series.

The limestones do not appear at this horizon, and the shales only play a subordinate, and all but insignificant, part, although at times they seem to have some relation with the auriferous deposits.

The fact that quartz alone is present in the pebbles and gravel of these conglomerates and quartzites (either in the form of quartz properly so called, or in the condition of quartzite which has already gone through one stage of sedimentary deposition, followed by erosion) simply proves that all these rolled constituents, the evident product of denudation of previously existing rocks, have been subjected to the agencies of mechanical trituration sufficiently long for the destruction of all rocks and minerals less resisting than silica. For it is extremely probable that when these beds were laid down, the waters, whether mountain-torrents or sea-currents, which carried off their fragments in suspension, laved not only banks of quartz, but rocks of all sorts and kinds, such as granites, gneisses, crystalline schists, limestones, etc. It is known, however, that if a variety of rocks be subjected to the action of the waves or of running water, if we note, for example, a river flowing from the depths of a mountain-massif of crystalline rocks into a plain, as we get farther and farther away from the mountains the pebbles of friable rock crumble down gradually, the schists first of all, then the granites and granulites, then certain porphyries or harder basalts, until nothing but quartz remains. The writer is acquainted with several exclusively quartzose conglomerates of this kind, especially among the Primary rocks of France. And to cite only one fact, but observed, on the other hand, among much more recent deposits, there exists throughout the Bourbonnais and the Nièvre, between the Allier and Loire rivers, a great fluviatile formation of Pliocene age, occupying an extent of 15 to 20 miles. This formation received from the writer the name of "Sands of the Bourbonnais." It is entirely made up of quartz-pebbles and quartz-sands, with a few seams of clay—evidently the final product of the transport of material from the very varied rocks of the Central Plateau. Here, again, quartz is the sole survivor.

The pebbles in the Witwatersrand auriferous conglomerates are of the most diverse dimensions, from the size of a pea up to 4 inches and more in diameter. They consist of different varieties of quartz and quartzite, among which one especially notes bluish-white, vitreous or hyaline quartz, known in all countries as characteristic of ancient rocks, where it is the frequent associate of gold and tin. There are also smoky-black quartzes and pebbles of a dull black quartzite of very fine texture, and grains of blue quartz analogous to those which occur in the porphyroids

of the Ardennes. Such is generally the composition of the Main Reef Series, but in certain very thick conglomerates with big pebbles, which often occur in the roof of the reefs (such as those of the Geldenhuis Valley, Elsburg, De Paaz, Kimberley, and battery reefs in the south), one finds in addition pebbles of white quartzite analogous to that which encases the conglomerates at roof and floor, and sometimes pebbles of banded quartz, striped black or dark blue, often extremely pyritous; these are especially noticeable in the Geldenhuis Valley reef and in that near Heidelberg, known as the striped pebbles reef.

One curious feature of these pebbles is that they often present, and that at all depths in the mines, sharp or scarcely blunted angles. This appears at the first glance scarcely compatible with the idea of prolonged trituration which the writer had put forward to account for the exclusively quartzose character of the conglomerates.* But we have here an occurrence which is far from exceptional among the ancient conglomerates known in other countries, and it may be doubtless explained on the hypothesis that certain big pebbles got broken up on the spot where their angular fragments now occur. These were deposited without having had the time to get rolled, and it will be noted that some of these polyhedral pebbles seem to dovetail into each other as if they had been just split up (perhaps after deposition), and then almost immediately re-cemented by silica percolating into the fissures (Fig. 7, Plate XXIII.).

The writer would also draw attention to the frequent occurrence of flattened pebbles, whose form instead of being roughly spherical is distinctly ellipsoidal. Pebbles of this kind are sometimes found massed together at certain horizons (especially in the south reef) parallel to the general stratification. It is true that this flattening seems to have been at times accentuated by a kind of lamination of the strata originating from some mechanical agencies posterior to deposition, and of which we find elsewhere many other traces; the quartzes are then cracked and fractured. But, on the whole, the flat pebbles are the ordinary flat pebbles which are only to be found in marine formations, the flatness being due, as is well-known, to the nature of the motion imparted to the pebbles by the waves, a motion which is oscillating rather than rotatory.†

If to the above observations the very striking fact be added that the conglomerate series stretches over a vast extent of country (despite some

* Experiments made by Prof. Daubrée (*Comptes Rendus*, vol. xliv., page 997) show that, after a journey of about 15 miles through a revolving cylinder immersed in water, angular *débris* are transformed into pebbles similar to those which now occur on most sea-coasts.

† Prof. De Lapparent, *Géologie*, third edition, page 237.

modifications of a secondary order, which recur very often, and to which reference will be made farther on) showing remarkably constant features; if we note, further, that certain especially characteristic bands, such as the Kimberley, bird, and south reefs, may be followed, without straining over much assimilations and analogies, from one end of the Rand to the other, we arrive at this result, deduced from all the observed facts—that the quartzites and conglomerates constitute (quite independently of their auriferous matrix or cement which is possibly a local feature) one vast formation of apparently marine origin, which was probably first of all deposited in a practically horizontal position; and that it was subsequently thrown into folds; also that the gold-bearing strata of the Witwatersrand with their well-known dips are simply one synclinal fold of this formation. To this point the writer will presently recur; meanwhile he is glad to know that his views as to the origin of the conglomerate series are shared by Messrs. Draper, Goldmann, and others.

One word more as to the general facies of the conglomerates in the Witwatersrand. These conglomerates have been, so to say, emblazoned with a reputation for regularity which the results obtained in mining industry may, to some extent, justify (always excepting some limitations which have yet to be discussed), but taken literally, this word "regularity" is apt to impress one with erroneous notions as to the geological arrangement of the deposits.

Supposing, for example, we look at any gallery or drift in one of the Rand mines, or at one of those diagrams of assays and trial-workings, wherein for every 30 feet or so, the thickness of the stuff and the tenour of the ore is written on the plan of the gallery, and then if one transforms the figures thus recorded into a graphic diagram (as has been done in Figs. 29 and 30, Plate XXV.) it is seen at once that the reputed "regular" reefs constantly change in dimensions as they do in tenour. Nor is the change unimportant, for in a distance of 60 feet or so they will expand from a few inches to many feet in breadth. This irregularity, of which an example has been given here, taken quite at random from one of the best-known mines on the Rand, is so far from being an exception that it may be regarded as a general rule.* It would be surprising if

* Figs. 29 and 30, Plate XXV., represent corresponding portions of the main reef leader and the south reef in the same part of the mine. Of the three curves, the first represents the variations in thickness at each point, the second, those of the tenour in gold, according to the laboratory assays; the third, the variations in richness, that is, of the product of thickness multiplied by tenour. These two last-named factors in no wise compensate one another, as some persons have declared, after too brief an investigation. Assay and trial-working diagrams being of an essentially confidential nature, the writer does not consider that he is in a position to state here the name of the mine concerned, but this reticence by no means diminishes the importance of the example from the geological point of view.

this were not the case, and such "regularity" as that supposed would be really unexampled in a geological formation of shore-origin, as are these quartzites and conglomerates.*

Apart from these variations of thickness in a single reef, apart from these expansions and contractions, one notes, whenever it is thought worth while to make careful observations, local branchings off or ramifications of the reefs into two veins which come together a little farther on. One may observe also sandy seams appearing in the middle of the conglomerates, or, conversely gradual passages from sandstone into conglomerate, etc. Interesting occurrences of this kind may be noted in the sections of the Simmer and Jack mine reproduced in Figs. 23 to 27, Plate XXIV.

In view of the variations upon which the writer has just laid so much stress, it may well be asked whether he is not indulging in the exercise of an over fertile imagination in pretending to follow—as he proposes to do in the subsequent pages—the Main Reef Series or any other conglomerate-bed for more than 20 miles from one end to the other of the Rand. Indeed, the first impression one gets in visiting the mines of the district is that it is extremely difficult, if not impossible, to distinguish one reef from the other, and therefore that the correlation of two distinct fragments of reefs —particularly when they are separated by a fault which sometimes brings two different reefs into line with one another—is extremely hypothetical, and is perhaps even fathered by the wish to dub the reef at which one is working with a name which sounds well, as belonging to a reef known as a rich one on other properties.

In point of fact, a Witwatersrand reef does not constitute, as we Europeans are too prone to believe, an absolutely definite unit, of constant facies and immediately recognizable wherever met with by means of some distinctive feature.

Often it is quite difficult enough to distinguish barren "country rock" from the ore-bearing rock, not to speak of distinguishing one gold-bearing reef from another. The perfect similarity of the quartzite-bands which form the hanging and foot-walls of the different conglomerates is another reason for exercising much caution in correlation.

However, in the long run, the confusion of reefs begins to resolve itself into some sort of order in the observer's mind, and he soon contrives to form of each reef a sufficiently definite mental picture to be able to distinguish them with fair success, not, perhaps, from a hand-specimen or

* The existence of conglomerates extending over a breadth of several miles is not peculiar to the Transvaal, but even so it is very difficult to fit in such an occurrence with the comparatively insignificant breadth of recent shingle-formations along our own coasts.

from a single working-face, but, at any rate, from a certain length of galleries or drifts. The writer was on several occasions struck with the constant characters observable at mines far distant one from the other, shown by such reefs as the south reef (made up of thin seams of flattened pebbles), the main reef leader (usually superimposed on a clayey bed with a quartz-vein), the main reef (usually consisting of 3½ to 7 feet of conglomerate with rounded pebbles about the size of walnuts), and above all, the bird reef (with small pebbles of the shape of bird's eggs), the Kimberley reef (with enormous pebbles, among which many are of quartzite), and lastly, the black reef (with its masses of pyrites and its very high-grade, irregular assays). He noted also that the reefs which thus owed their names in a large measure to their general appearance, always occupied the same relative stratigraphical position, and could sometimes be directly joined up from one locality to the next.

The writer is therefore quite disposed to believe that although there is discontinuity, and lenticular arrangement, of any given vein taken singly, the *ensemble* of these veins is nevertheless in some sort continuous from one end of the gold-workings to the other.* This idea will be adhered to in the description which it is proposed to give, although the writer will in no case attempt to slur over the difficulties which will often be found in the path of correlation, difficulties which are especially observable, as Mr. Goldmann remarks† in correlating the Bothas reef in the west,‡ or those of Modderfontein and Van Ryn in the east with the reefs of the central portion of the Rand.§

This group of veins of auriferous conglomerate to which the writer thus attributes persistency over a considerable distance strikes, on the whole, east and west, and dips south.

Throughout the eastern district, starting from the Witwatersrand gold-mine on the Eastern Rand, at Van Ryn, Modderfontein, etc.,

* The author will, farther on, have the opportunity of repeating that he draws no conclusion of industrial consequence from this purely geological opinion. It appears to him that the importance for a mine of having such and such a name given to the reef which is being worked in it has been immensely exaggerated. In matters like this only one thing need be taken account of—a trial and assay, conducted at leisure, and in a practical manner.

† *Op. cit.*, vol. i., page xxv.

‡ According to Mr. Draper's latest conclusions the Bothas reef of the Champ d'Or is not the main, but the Elsburg reef.

§ In these attempts at correlation we must bear in mind a point which complicates the work for anyone who has neglected to observe the facts for himself in each mine, and that is the instinctive and very natural habit which all mine managers have of enlarging their vein and simplifying the section by thrusting into one bank of conglomerate all the intermediate seams of sandstone without making the slightest mention of these. In conducting a geological investigation it is, of course, impossible to rely absolutely on evidence of that order.

one notes the occurrence of a layer of shales, becoming thicker and thicker, intercalated in the reef series, and forming the foot-walls of one of the principal reefs. The same thing is observed in the south, towards the Nigel mine, while in the west this band of shales is barely indicated (and the writer is by no means certain that it is here an indicator) by a mere clayey film or skin, as it were, which has much the appearance of a salband, due to the sliding of the beds one over the other.*

If, now, we turn westwards once more, the strike of some of the reefs there, such as the bird reef, is seen to be sharply deflected, taking a north-and-south direction, a course which it is also found to follow in the Randfontein reef, and this on fairly plausible grounds has been supposed to hold good for the whole series (Fig. 5, Plate XXII.). Hereabouts, moreover, the dip of the strata being generally very low and approaching the horizontal, there is a resulting complication in the outcrops, which has, so far, not been disentangled.

The north-and-south strike, however, is a merely local accident traceable for about 5 miles. When that distance has been traversed there are indications that to the southward the strike resumes its east-and-west course right up to a granite-dyke, along which a line of fault throws the beds back northward. We have here a large district only half explored, where the occurrence of the reefs at some point or other (whether visible or masked by later deposits matters little) may be considered highly probable, and after crossing a gap of 25 or 30 miles we find ourselves in the district of Buffelsdoorn and Klerksdorp. Here the workings are in a series of quartzites and conglomerates striking north-east and south-west, with an easterly dip.

Throughout the district lying between Modderfontein and Buffelsdoorn, which we have just been rapidly surveying, the conglomerates dip to the south or south-east with extremely variable gradient, varying indeed, as one may say without much fear of exaggeration, between the horizontal and the vertical, and the frequency of these variations may be gauged on inspecting the accompanying map (Fig. 8, Plate XXIII.). This map represents the south reef, as if it lay bare to the surface, by contour-lines 164 feet (50 metres) apart, and hachuring on the same principle as that in ordinary geographical maps, the shading being darker or lighter according as the slope is steep or gentle. It shows at the outcrop some zones cocked up particularly high, as in the Robin-

* Unless we may correlate it with the shaly series occurring some distance off in the foot-wall of the main reef at Hospital Hill. Here, however, we are trenching on stratigraphical problems which still await solution.

son, Henry Nourse, New Chimes, and Van Ryn mines, others where there is positive flatness (difficult to symbolize on so reduced a scale) with low wave-like undulations, as at the Durban Roodepoort, Simmer and Jack, and Modderfontein mines. The map also throws into relief this fact, which holds good for the Rand generally, that the dip gets nearer and nearer the horizontal in each transverse section the deeper one goes down.* Lastly, a curve has been drawn showing graphically the average assays obtained from each mine working at the end of 1895. It maps out a certain number of rich zones gradually becoming poorer along the edges [of the field], and intermediate poor zones (Fig. 9, Plate XXIII.). The superposition of the two figures seems to point to a certain relationship between the richness of the reefs and their pitch, but this is not brought out with sufficient clearness to justify the deduction of any geological conclusions. The writer believes, nevertheless, and will restate that conviction farther on, that the present dip is posterior to the deposition of the gold; but it is quite possible that the variations of the dip are connected with some one of the phenomena already described.

In the south-east, the workings in the direction of Nigel and Heidelberg cut into other beds of quartzite and conglomerate. These are probably the same beds as the preceding, re-appearing in the other limb of a synclinal depression, but it is not as yet possible to prove this by precise correlation from bed to bed. It remains for us to examine the *ensemble* of this arrangement of the strata, the importance of which, from the point of view of the industrial future of the district, is evidently paramount.

The auriferous formations of the Witwatersrand have often been described as filling an ancient lake of not very extensive area. The shores of the lake even have been mapped out, following pretty closely the present outcrops from Klerksdorp to Johannesburg and Heidelberg. In connexion with the same hypothesis reference has been made to deltas formed by torrents, but the writer's opinion, as the reader has already been made aware, does not accord with these hypotheses. The deposits have none of the characters of lacustrine formations, which the writer has had occasion to study very closely in connexion with the Coal-measure and Tertiary lakes of the Central Plateau of France: they have all those of a great marine formation, whereof the conglomerates and coarse sands probably constitute the littoral facies, here considerably developed.

* Compare the series of sections, Figs. 10 to 22 in Plates XXIII., XXIV., and XXV.

Leaving out of account, for the present, the auriferous impregnation which does not necessarily characterize the whole of the geological formation of conglomerates in which it occurs, nay, which must be considerably less than co-extensive with it, the writer considers that the series of quartzites and conglomerates of the Witwatersrand forms a great synclinal fold striking north-east and south-west, between the two lines of outcrop mentioned above (the one from Modderfontein to Buffelsdoorn, the other from Nigel to Heidelberg). This synclinal, in common with all other folds of the same character, is deflected, widened, and drawn out in more or less complex fashion; and it is highly probable that the aforesaid synclinal extends either eastward or westward far beyond the zone to which attention has been drawn hitherto.*

Further, it may be noted that such synclinal depressions present, by a well-known phenomenon on which Mr. Marcel Bertrand has recently thrown much light, very nearly orthogonal transverse folds: these may bring to day, along some anticlinal ridge perpendicular to the general axis of the basin, such and such an horizon of the series. If there really were running north and south from Modderfontein to Heidelberg through Geduld an outcrop of the reef, such as is tentatively indicated on most maps by dotted lines, it would be explicable by an upthrow of the kind hinted at, and that would in no wise prevent the synclinal with all its reefs from continuing beyond the point of upthrow. As a matter of fact, however, the country is so completely covered either by drift or by Karoo Beds, that this hypothetical outcrop must for the present be left in the domain of theory.

If we turn to the small geological map accompanying this paper (Fig. 5, Plate XXII.), based partly upon a very recent map drawn up by Messrs. Draper and Wilson Moore,† we shall find that it confirms the views herein expounded. First of all, one notes in the north the *massif* of granite and gneiss previously studied north of Johannesburg. This *massif* appears to occupy the site of an old anticlinal, very marked in its prolongation south-westward.

This is succeeded by a long zone of the conglomerate series striking east and west. Herein the auriferous bands form sinuosities which the writer has endeavoured to bring out clearly. Indeed, if the map were something more than the imperfect sketch it is, these sinuosities would be

* The exact verification of this hypothesis would have necessitated a long and minute exploration of the ground which the present writer had no time to make, but all that he did see tended to confirm it.

† The writer has completed this map in some particulars, and especially by tracing on it the auriferous reefs, which he was surprised to find omitted.

doubtless repeated in the external contours of the series. Towards the west, for example, the sharp deflection of the reefs from Luipardsvlei to Randfontein and Middelvlei, and then their return to their original direction, may well correspond to some north-east and south-west fault, marked a little farther north towards the Limpopo by the abnormal contact of the granite and the dolomite without intercalation of conglomerates.

It is not easy to say whether the granite is anterior or posterior to the series of conglomerates, but the extreme metamorphism of the whole of the Witwatersrand Series (shales, sandstones, etc.) would lead one to infer that the granite is later in age. This conclusion may be deduced also from Mr. Draper's map, as regards the granite-dyke, along which, from east to west, he has shown the whole series thrown back.

Beyond this upthrow the series of conglomerates, which we are now considering in its entirety, without particular reference to its auriferous bands, takes up again a north-easterly and south-westerly course, forming a very distinct anticlinal ridge as far as Buffelsdoorn and Klerksdorp, and continues still farther westward of the Vaal river, in the direction of Kimberley.

The geological pendant of this zone of conglomerates recurs south of the synclinal, also with a north-east and south-westerly strike, but approaches more nearly, first, the north-and-south line from Nigel to Heidelberg, then the confluence of the Klip river with the Vaal (Vereeniging), on the line of railway from Johannesburg to Cape Town, and lastly, the valley of the Vaal, south of which the quartzites are found banked up against granite.

Looking on the map at the general features of this synclinal, one notes that in the east the two limbs appear to approach one another, the deposits of the overlying formations (dolomite and Magaliesberg Series) disappearing between them. It is indeed possible that what the writer explained above has occurred, namely, a transverse uplift, which closes together the contour-lines representing the outcrop of the conglomerate beds, and cuts them momentarily short. But it is very possible, too, that this closing up is more apparent than real, due merely to the disappearance by erosion of the overlying strata. At any rate the strike of the reefs at their ends plainly shows that it is not so easy to correlate the separate fragments as is generally supposed, that is directly from Modderfontein to the Nigel mine. Even if the contour-lines did close up, they would probably open out again a little farther on, along the prolongation of the same synclinal.

Through this series of conglomerates, whose general features have now been described, and which it is proposed to study presently in detail, the following section may be drawn, in ascending order. The section is very diagrammatic—if one may use that term of a description—because, as the reader has seen, there are continual variations from one locality to the next in thickness, number, and intervals of the beds. It will, however, give some idea of their stratigraphical relations.

	Feet.
Granite	—
White quartzites	1,150
Sandstones and ferruginous shales (for details see section V U through Doornfontein Farm)	1,540
Quartzites forming the foot-wall of the Rietfontein or Geldenhuis Valley reef, about	4,000
Rietfontein Reef Series—	
North reef, very little worked	½ to 1
Quartzites	50
Quartzites containing two seams of pebbles. These are worked (middle reef and middle reef leader)	4¼
Quartzites	50 to 65
Stable reef: conglomerate with small pebbles ...	5
Quartzites	820
Magnetiferous grits, quartzites and shales of Slaughter House Hill	700
Quartzites with thin bands of conglomerate	330
Quartzites forming the foot-wall of the Main Reef Series	2,300 to 2,600
Main Reef Series—	
North reef rarely worked	¼ to 3¼
Barren quartzite	50 to 65
Main reef (thick bed of conglomerate) assaying 10 to 15 grammes of gold	5 to 26
Barren quartzite, thinning out to nothing on the Crown Reef, Bonanza, Jubilee, Village Main Reef, City and Suburban, 6½ to 10 feet thick at the Robinson mine, and attaining 65 feet in the Wemmer and Salisbury mines	0 to 65
Foot-wall of the main reef leader, clayey salband frequent, with quartz-veins	0 to ¼
Main reef leader, conglomerate assaying on the average 10 to 35 grammes. The maximum gold tenour is often found in the hanging-wall of the leader	1 to 3¼
Barren quartzite with a middle reef not worked ...	100
South reef, quartzite containing several veins of conglomerate, generally thin and having flat pebbles, with intercalated sandstones sometimes thinning down to nothing. The richest portion is often at the base where one sometimes notes (Crown Reef, etc.) a segregation-vein of white quartz.	

	Feet.
This reef is the richest of all those in the centre of the Rand, and assays on an average 15 to 40 grammes	4¼
Quartzites	1,300 to 1,600
Bird reef	13 to 20
Quartzites	1,300 to 1,600
Kimberley reef	33 to 65
Quartzites	4,000
Elsburg reef	65
Quartzites	8,200
Amygdaloidal porphyrites of the Klipriversberg ...	4,000
Black reef	16 to 20
Quartzites	200
Dolomitic limestones	5,000
Gatsrand and Magaliesberg Series (quartzites)	—

In the Main Reef Series, which is the chief one worked, one may take it that the average total thickness of reef commonly hewn down in any mine is 6½ feet, there or thereabouts, and it does not matter, so far as regards this average, whether the mine is working two reefs or one.

The series is, as a rule, bordered by two very hard bands, which protrude on the surface, and have been used as indicators to follow the outcrop. They are known as the "red bars."

Attention has just been called to the auriferous horizons of the conglomerates. Immediately above these come, unconformably, according to Mr. Draper, dolomites, with local intrusions (south of Johannesburg) of amygdaloidal porphyrites almost exactly at the contact of the quartzites and dolomites. These dolomitic limestones,* or analogous formations, cover vast areas in Southern Africa, and the somewhat romantically imaginative conclusion has been jumped at that the rich gold-bearing conglomerates lay everywhere beneath them.

A few words in passing may be devoted to the amygdaloidal porphyrites of the Klipriversberg, and then we will proceed to describe the dolomites, which are of very great geological interest.

Between Johannesburg and the outcrops of the black reef there rises at the Klipriversberg (Fig. 5, Plate XXII.) a long ridge of amygdaloidal porphyrite, about 4,000 feet in breadth, and 20 miles in length: it overlies the series of quartzites, almost exactly at their junction with the dolomitic limestones.

This porphyrite appears to have crystallized out on top of the quartzites, at the epoch of the great physiographical change which was

* Messrs. Hatch and Chalmers put these limestones below the conglomerates, but this appears to be in contradiction with all recorded observations.

marked by a stoppage in the deposition of quartzose sediments, before the calcareous deposits began to form. There is no doubt that the pyritiferous conglomerate of the black reef and the horizontal layers of quartzite which overlie it, were deposited upon the porphyrite after its extrusion, and that it was not the porphyrite which subsequently thrust itself between the black reef and the underlying rocks. The best proof of this contention is that the black reef, which, as already mentioned, partakes more of the nature of a breccia than a conglomerate, frequently contains fragments of the subjacent eruptive. The reef, as seen for example at the Orion mine, was laid down in the depressions and hollows of the porphyrite—which seems to have been subjected to certain mechanical agencies in the interval; and, on the other hand, the reef is overlain by very regular, nearly horizontal, beds, these forming a sharp angle with the beds on the foot-wall or floor.

The dolomites, usually of a blackish hue, are often permeated with siliceous venules: these probably have something to do with dykes of ophitic diabase, passing into porphyrite, which traverse the calcareous rocks. The dolomites form two long east-and-west zones in the midst of the synclinal of the Witwatersrand: the northernmost zone appears near the Orion mine, above the black reef worked at that point.

The section at the Orion mine, to which we shall recur later on, includes from roof to floor: (1) quartzites; (2) an eruptive igneous rock, upon which lies the nearly horizontally bedded reef; (3) quartzites again, and, a little farther south, dolomites lying unconformably upon the quartzites. Through these dolomites borings are now being made, with the view of striking the prolongation of the reef.

Identical dolomitic limestones have been recorded at several other points in the same stratigraphical position above the black reef, as, for example, at the Eastleigh mine, south-west of Buffelsdoorn. Here the black reef is actually worked under the limestones. Again, the same rocks are found at the head of the Wonderfontein river, where they are overlain by strata, which will be described later on under the name of the Gatsrand Series. At Vereeniging, on the railway-line from Johannesburg to Cape Town, analogous limestones containing, according to Mr. Draper, Carboniferous fossils, have been traversed by a trial-boring, and a similar boring at Wettdrift (Vaal river) struck the black reef 23 feet below the dolomites. Finally, over the whole of the western portion of the Rand, a long anticlinal of quartzites, previously mentioned in these pages, has both flanks covered by these dolomites.

Mr. Draper has drawn attention to the following points:—At Krondraai, a series of quartzite-veins and auriferous slates, likened by him to the black reef (although the conglomerate is absent here) is topped by dolomites. Similarly, at Malmani (Kaffirkraal), the limestone overlying the quartzites contains numerous very distinct venules of auriferous quartz, with galena, cinnabar, and blende. The limestone here is practically horizontal, and contains tremolite in its upper portion.

The occurrence of these auriferous veins in the limestone is of considerable interest. Possibly they do but represent a secondary segregation of the subjacent ores, brought about by that circulation of the surface-waters which is always going on in limestone-fissures. But it is curious that mercury and zinc should crop up here, metals of which, as a rule, not even a trace is found in the ores of the Rand; and one might be tempted to infer from this the existence of an entirely independent set of veins. At all events, there seems to be a good deal of analogy betwixt this restricted occurrence of auriferous venules and the new gold-fields of the Kimberley district (Herbert gold-fields, etc.) These also consist of short veins in limestone, and they have been the subject quite recently of much attention.

Another section of these dolomites, taken at the Klipriversberg, may be quoted on Mr. Draper's authority. If one draws a section of the Klipriversberg coming from the southward, from Eagle Hill, the first rocks that one meets with are the dolomites, with their characteristic associates, the siliceous bands, dipping about 10 degs. Below them, near the Klip river, comes the Black Reef Series (Vesta Gold-mining Company's mine) accompanied by quartzites dipping south at the same angle. These are succeeded by the amygdaloidal diabase at the Klipriversberg and the conglomerates, which go on right up to the granite without any further intercalation of limestones.

To complete the characterization of these dolomites it only remains to add that, like many other rocks of the same kind, they have given rise by the circulation of underground waters to a large number of caverns, and sometimes to swallow-holes, wherein the rivers are lost—phenomena observable along the banks of the Vaal and in the Mooi valley towards Potchefstroom.

As regards their exact age, the available evidence is extremely scanty. The Carboniferous fossils found at Vereeniging, the fossils of similar age (*Terebratulæ* and other brachiopods), recorded by Mr. Sawyer from the Zwarteberg Mountains as associated with thin seams of coal, and an hypothetical correlation with the Table Mountain Series of the Cape of Good Hope, these constitute all the data to hand.

The latest Palæozoic strata that occur in the Witwatersrand synclinal are the Gatsrand Beds, made up of rather narrow bands of quartzite, which have been sometimes confounded with the great mass of quartzites that accompany the conglomerate series. They occupy the uppermost portion of the ancient rock-formations immediately below the Karoo Series, which is strongly unconformable to them.

These Gatsrand quartzites are similar to those of the Zuurberg, Zwarteberg, Witteberg (Cape Colony), and also to those of Kowie, considered as belonging to the Upper Carboniferous.

To the same horizon are referred the very characteristic Magaliesberg Beds: these form a small range, striking east-and-west, west-north-westward of Pretoria.

Before proceeding to describe the more recent Karoo Series, it may be well to summarize as follows the older geological formations, which have been briefly reviewed in the preceding pages. We will tabulate them in descending order:—

	Feet.
Karoo (Permian and Trias)	
Unconformity.	
Thin quartzites of the Gatsrand (Middle Carboniferous)...	
Magaliesberg and Pretoria Beds: Dolomitic limestones (? Lower Carboniferous) about	6,500
Quartzites forming the hanging-wall or roof of the black reef	16 to 33
Unconformity.	
Black reef	
Amygdaloidal diabase of the Klipriversberg	8,000
Witwatersrand Series of auriferous quartzites and conglomerates (Lower Devonian)	20,000 to 23,000
Clay-slates, ferruginous rocks, and quartzites of Hospital Hill	3,300 to 6,600
Unconformity.	
Granite and gneiss	

As giving some indication of the age of these beds, it will be noted that the Karoo Series, near Johannesburg, contains Permo-Triassic fossils. On the other hand, certain dolomitic limestones at Vereeniging are Lower Carboniferous. In order to arrive at a more precise determination, some writers have appealed to a rather far-fetched correlation between the ancient formations in the neighbourhood of Cape Town and their presumed geological equivalents in the Transvaal.

Table Mountain, which lends so great a charm to the view of Cape Town, as seen from the sea, has a basement of normal granite forming its lower rounded slopes, above which rise, cut out in steep cliffs, hori-

zontal strata of the ancient series: shales of no very great thickness, followed by sandstones with a few conglomerates. These latter constitute the actual "Table." The geological structure of the mountain is easily ascertained in the course of a short excursion. The unfossiliferous sandstones of Table Mountain are in other localities overlain by Bokkeveld Shales, with Upper Devonian fossils, and they are the sandstones which it is sought to correlate with the gold-bearing rocks of the Witwatersrand.

The section in the south of Cape Colony is as follows :—

Zwarteberg Series, correlated with the Gatsrand and Magaliesberg formations (Middle Carboniferous).

Unconformity.—Dolomites of the Malmani Plateau, Damaraland, Kaap Range, and Griqualand West, correlated with those of the black reef and Zoutpansberg (Northern Transvaal) (Lower Carboniferous).

Unconformity.—Micaceous shales of the Bokkeveld Series, with Upper Devonian fossils (wanting in the Transvaal). Sandstones, with some conglomerates, of Table Mountain, correlated with those of the Witwatersrand and Zululand, etc. Clay-slates, without fossils, correlated with the ferruginous beds of Hospital Hill.

Unconformity.—Occasionally: Malmesbury Beds resting on Namaqualand strata, and possibly representing Cambrian and Archæan deposits.

Granite.

In South-eastern Africa, towards Swaziland, and in the gold-bearing districts of De Kaap or Lydenburg, there is intercalated, below the beds of Hospital Hill and the Witwatersrand or Table Mountain Sandstones, a considerable series of argillaceous, talcose, and chloritous schists, often containing interstratified gold veins. This series has been described by Prof. Schenk under the name of Swazi or Lydenburg Beds.

2. *Karoo Formation.*

Over the whole of Southern Africa, the Karoo Beds represent a truly remarkable formation of continental vastness, the deposition of which must have gone on during long geological ages without suffering interruption from any earth-movement of importance, and which, moreover, seems to have been at no time displaced or thrown into folds, but has been simply cut off by faults along the great lines of sagging which occurred in Cretaceous times, and ultimately brought about the formation of the Indian Ocean.

These rocks, which Prof. Suess has correlated with analogous beds in India, on the supposition that the two continents were at that time united across Madagascar by the immense plateau of Lemuria, did undoubtedly once cover the whole of the Witwatersrand gold-bearing area, and they are not found there now, simply because they have been denuded away. Many scattered fragments of them are left as relics in the south

and east, where they still occupy a large extent of ground. Even where they have entirely disappeared, thick beds of drift, which are the result of their erosion, still remain, and these mask the outcrops of the auriferous conglomerates. The great erosion of which we have here an indirect proof must have denuded away from the upper portion of the gold-bearing strata a considerable mass of ore; and one is somewhat surprised that nothing more has resulted in the shape of auriferous alluvia than the very meagre deposits washed for gold on the first discovery of the country, and now abandoned.

Such remnants of the Karoo formation as are met with around Johannesburg appear to belong only to its upper portion, the lower horizons known as the Dwyka and Koonap Beds being almost entirely absent.* In view of the fact that workable coal is frequently met with in them, they have even been classed, as a general rule, with the very topmost beds, the Stormberg Series. This is considered in most parts of Southern Africa to have the coal-seams at its base and is put in the Rhaetic system. Fossils are of extremely rare occurrence in it: nevertheless, Prof. Schmeisser found at Holfontein colliery in the Wilje river-basin (Middelburg district), which lies pretty far north, some remains of *Glossopteris* and *Schizoneura*. He has, moreover, drawn attention to a specimen of *Glossopteris* collected by Dr. Simon in the same district at Olifant river. Thanks to information supplied to the writer by Mr. Brisse, mining engineer, he was enabled to find a plant-bed not more than 1½ miles south of Johannesburg, at Francis, close to a great reservoir built south of the Ferreira.† This deposit consists of a very small mass of shales and sandstones with an extremely thin seam of coal, in which exploration-work had been previously carried on without sucess. The fossil plants collected at this locality include, according to Mr. Zeiller, who has been so good as to examine them, *Glossopteris Browniana*, Brongt., *Gl. communis*, Feistm., *Gl. angustifolia*, Brongt., *Vertebraria indica*, Royle, *Phyllotheca*, sp., and *Noeggerathiopsis Hislopi*, Feistm.

The presence of these various species of *Glossopteris* leads one to refer the deposit to the Beaufort Beds, as the flora of the Stormberg group does not include any examples of that genus. The age of the deposit would then probably be Upper Permian or Triassic (middle portion of the Lower Gondwánas of India), whereas the Stormberg group belongs to the Rhaetic, or, at the earliest, to the Upper Trias. From this we are forced

* Prof. Schmeisser, however, speaks of a rock collected on the Modderfontein farm, 7½ miles east of Boksburg, which he correlates with the Dwyka conglomerates.

† This is probably the Rosettenville deposit mentioned by Mr. Goldmann as containing *Glossopteris*, *Cyclopteris*, and other Triassic plants.

to the conclusion that at least a part of the coal-formations of the Transvaal, namely, that including the seams of Olifant river and Holfontein colliery, being in immediate correlation with the above-mentioned *Glossopteris*-beds, is to be placed, not in the Stormberg Series, but in the older Beaufort group.

Again, Mr. Goldmann puts on record at Vereeniging, 30 miles or so south of Johannesburg, coal-beds unconformably overlying the dolomite; and he avers that they contain, in company with Triassic plants, two Carboniferous fossils, *Lepidodendron* and *Favularia*.*

The Karoo Beds which are exposed in the Transvaal, Natal, and Cape Colony, contain at many localities coal-deposits of considerable thickness and industrial importance. These are being worked at the following places, among others, going from north to south:—

1.—In the Transvaal, at Vereeniging (Lewis and Marks); Holfontein (Douglas); Olifant river, near the Wilje river (an affluent of the Rhenoster, which in turn flows into the Olifant river), south of Middelburg, and not far from the railway-line from Pretoria to Lourenço Marquez, Delagoa Bay; those of Boksburg (Brakpan colliery, Springs, Cassel colliery at Daggafontein, etc.), immediately east of Johannesburg.

2.—Those of Swaziland.

3.—In Natal those of the environs of Newcastle and Ladysmith, near the railway-line from Johannesburg to Durban.

4.—In Cape Colony those of Parys, almost on the border-line of the Transvaal at the Vaal river; those of Kronstad, on the railway-line from Johannesburg to Cape Town; those of Cyphergat and Indwe, near the branch-line from Springfontein to East London; finally, those of Molteno, Bushman's Hoek, etc.

The Cyphergat coal, which has so far formed the staple fuel of the De Beers Company's diamond mines, is equivalent to about 51 per cent. of the same weight of Welsh coal. But at the Indwe mine, recently purchased by the De Beers Company, the seam, 6½ feet in thickness, save for a few shaly streaks, is said to be equivalent to about 70 per cent. of English coal.

The Boksburg coal, which is practically alone used on the Rand, is more anthracitic and more ashy than that of Middelburg, where seams of coking coal are found. Consequently it is inferior to the Middelburg coal; but it gives very fair results in boiler-firing, and it is so very easily worked that it could doubtless be obtained at a low price at the gold-mines, were it not for the excessively heavy freight charges.

* *South African Mining and Finance*, vol. i., page 24.

B.—Special Study of the Witwatersrand Gold-bearing Series.

*General aspect of the beds; their dip and subsequent dislocations; possible relationship between the richness in gold and the mineralogical character of the beds; successive descriptions of the various auriferous reefs from one end to the other of the Rand.**

In the preceding pages the general aspect of the Witwatersrand quartzite-and-conglomerate series, wherein the worked gold-bearing beds occur, has been sketched out, and the writer has endeavoured to show, amongst other things, that these strata formed one great synclinal, striking north-east and south-west, in such wise that throughout the Rand, properly so-called, from the Western Rand to Modderfontein, along the principal mining belt, the beds dip constantly southward, whereas on the southern limit of the synclinal, towards Nigel and Heidelberg, they dip northward.

It has already been shown, and will also be seen from the accompanying plan (Fig. 8, Plate XXIII.) that the amount of dip varies extraordinarily from point to point between the vertical and the horizontal. At some localities even, such as the Chimes mine, there is overfolding [angle of dip greater than 90 degs.] Nevertheless, whatever section we may take from north to south perpendicular to the axis of the synclinal, it generally seems, as one might expect, that, following the succession southward, the beds tend nearer and nearer to the horizontal as one approaches the axis of the synclinal. The black reef, which lies sensibly in that axis, is almost always horizontal, or nearly so.

A very characteristic circumstance, and a direct consequence of this arrangement of the beds in a basin, is that the pitch of a particular bed in a section, and, therefore, in a particular mine, constantly and very rapidly diminishes as one goes downward. Thus, for example, a dip of 70 or 80 degs. at the outcrop becomes only 30 degs. before one reaches a depth of 1,000 feet. There is no need to dwell on the importance of this fact from the industrial point of view.

A practical consequence of this is that, in order to work a given length following the inclination of the bed or reef, one need not go down in vertical depth anything like the distance which it would have been

* It is proposed to restrict the descriptions in this chapter to the stratigraphical aspect of the auriferous beds. The reader will not, therefore, be surprised if he misses in it particulars as to the mineralogical nature of the ores, the mode of crystallization of gold, etc., which will find their proper place in subsequent pages. Let it suffice here to recall the fundamental and well-known fact that the gold ores of the Witwatersrand are sedimentary beds of conglomerate and quartzite, wherein the gold occurs associated with iron pyrites in the cementing-material which surrounds and binds together the pebbles and grains of quartz.

necessary to go if the reef had kept its original dip. Wherefore, mining work being perforce limited to a certain depth (it matters not whether it is so limited by the material difficulties arising from increase of temperature, or simply by the excessive cost of extraction and pumping), the quantity of ore which one may hope to make sooner or later available for industrial purposes, is vastly greater than would otherwise be the case.* We have here touched the fringe of the great question of deep-levels.

Another result of this change of dip in the beds with the depth was a disagreeable surprise for the first companies who set to work in the gold-field. They had wrongly assimilated the auriferous band to a vein, in other words, to a practically vertical plane, and had, therefore, pegged out rather narrow claims in the direction of the dip of the reef, supposing that this would nevertheless be found throughout a given claim within the practicable working depth; whereas the reef, on account of its becoming flatter, was really no longer to be found in the claim, and cropped up in a neighbouring one.

The accompanying Plates (XXIII. and XXIV.) show a series of transverse sections on the same scale taken from west to east at different points of the Witwatersrand. The contour-lines of the reefs are seen to be described on these in a fairly regular sequence, and, save in exceptional instances, as at the Chimes mine (where the reef is especially dislocated by faults), or again at the Simmer and Jack (where, being nearly horizontal, a slight undulation causes it to take a completely different direction) it is seen that the line of greatest dip of the reefs follows in all localities, so far touched by exploration-work, a perfectly continuous curve. This is, of course, as it should be in the case of a group of strata formed of homogeneous beds regularly overlying one another, yet up to a certain point independent of each other; these beds being subjected to the mechanical force of intense folding will have curved up and slipped lightly over each other, much as the several cards in a pack which one would seek to bend by bringing its two ends together.

It is this slipping of the strata over each other which is undoubtedly answerable for the numerous clayey salbands, the results of the rubbing together of two contiguous beds along a longitudinal fault. The writer will have occasion in the subsequent pages to refer frequently to these salbands in his description of the Rand. Sometimes they include segregation-veins of milky-white quartz, while geodes or vughs of the

* On the other hand, the quantity of ore comprised in a claim becomes less the nearer the containing bed approaches horizontality, since the claim is limited by four vertical planes drawn from the four sides of the rectangle which form its surface-area.

In a general way, the experience thus gained so far tends to contradict the opinion at one time universally held, and still tolerably correct in the great majority of cases, that the gold exists solely in the conglomerates, and particularly in certain thin seams of big pebbles, such as the south reef, and often the main reef leader in the Central Rand. The example of Buffelsdoorn has been quoted, where the gold is present in very small quantity in fine-grained quartzites, and appears to be concentrated along certain pyritous and carbonaceous venules, with scarcely a trace of a pebble. The Rietfontein reef gives very high assays with quartzitic sandstones containing few pebbles. The Modderfontein reefs also, and that of the Nigel mine, are made up of fine-grained constituents, and yet they are reckoned among the richest. On the other hand, one notes between two auriferous reefs conglomerates with enormous pebbles, such as those of the Kimberley, Elsburg, and Geldenhuis Valley reefs, which do not, up to the present, appear very promising from the miner's point of view. Thus we see that there is no direct relationship between the dimensions of the pebbles or gravels and their richness in gold; and that if relationship there be, other influences must have intervened to counterbalance it.

Similarly, it is impossible to state that the gold and the pyrites which is intimately associated with it, have any well-marked tendency to accumulate, either at the base of the beds (as is almost invariably the case with gold placers), or at their summit. Sometimes they are found at the bottom, sometimes at the top, and at others midway between. Within the workings of a single mine one may, without any apparent reason, find the ore change from one position to the other. And, as the aspect of the ore furnishes no clue to its richness, and the gold can never be seen in it, one must resort for guidance to continual assays and analyses. For example, in several mines in the Central Rand—as the Ferreira and the Village Main Reef—one finds in the main reef leader and the south reef, which are some 100 feet apart, the rich portions facing one another on either side of the barren quartzite which separates the two reefs—that is, in the hanging-wall or roof of the main reef leader and in the foot-wall or floor of the south reef, which overlies the first-named.

Nor does the mineralogical character of the pebbles appear to have any distinct relationship with the richness in gold, as should be the case if the gold and the pebbles were derived from the erosion of one and the same quartz-vein. This is a point to which we will recur when describing the ores. It is true that in some mines importance is attached to

the presence of smoky black quartz, which is considered a good indicator. But experience very often belies this notion : the dark hue of the cementing-material, which is a consequence of the abundance of pyritous inclusions, and the presence of this pyrites itself are the sole fairly constant characteristics of the richer ores.

Another question of prime importance for the gold-mining industry is the more or less regular arrangement of the richer zones and their continuation in depth, and it is proposed farther on to devote a whole paragraph to the consideration of these points. Here it will suffice to say that, as a whole, the study of the Witwatersrand deposits leads us to recognize the existence of a certain number of particularly rich zones, very well marked on the diagram of mean assays (Fig. 9, Plate XXIII).* Looking still more closely into the matter, the observer will note that, as in all other metalliferous deposits, whatever be their origin, there is a kind of localization of the high assays, defining very irregular areas arranged in the plane of bedding. One will also note that, on meeting a fault or a dyke that has played the part of a fault, there is a sudden change (by reason of the suppression of the intermediate portions) in the gold tenour, and a rapid alternation from rich zones to poor and *vice versa*. Whence the more or less justifiable hypothesis that the rich ore-bodies tend to follow the general strike of the faults, which in the Central Rand is often north-east and south-west.

We have just been dealing with average tenours which one may expect to possess some constancy, some comparative regularity. Local tenours (assays) are on the other hand extremely irregular, as may be seen from the diagrams in Figs. 29 and 30 (Plate XXV.). These diagrams translate into a form readily appreciable by the eye the plans of trial-workings and assays, and they show how nearly approximate to the truth is a law which is very generally held as correct in the Rand—namely, that the richness in gold and the thickness of the reef vary inversely. It is usually believed at Johannesburg that by some kind of law of compensation a reef is the richer the thinner it is, just as if there had been only a given quantity of gold available for distribution within it. As a matter of fact there are very numerous exceptions to this rule.

* For many reasons this diagram cannot be made unimpeachably correct, because the average assays obtained from any selected mine may, without really indicating an alteration in value, appear to yield better or worse results according as the ore is sorted with great care or as much poor stuff is allowed to pass muster with the rich ore. Speaking generally, the increase in power of the stamp-batteries in a mine causes a diminution in the mean gold tenour, because low-grade ores, hitherto neglected, now get crushed along with the others. Nevertheless, the general distribution of the rich areas on the graphic curve does correspond to actual facts.

The variations of gold-tenour in depth, to which great importance is very rightly attached, from the point of view of the industrial future of the Witwatersrand, appear to the writer (from the evidence which he has gathered on inspection of the trial and assay-plans) to be of the same order as the already well-ascertained variations in direction. In a word, an alternation of rich and poor zones will probably be met with, but there is no reason to foresee any general impoverishment or enrichment of the deposits as one works deeper down. Considering the narrow dimensions of the outcrop-claims, it is natural enough to suppose that the immediately contiguous claims following the dip or deep-levels, will keep for some distance, at least, within the same zone, and will therefore be equally rich. But if one went some considerable distance farther along, it would be quite possible to find that to a rich zone at the outcrop corresponds a poor zone in depth, and *vice versa*.

It is now proposed to describe the principal reefs worked, laying stress on such points as are especially interesting for the geologist.

To begin with, in the north of the Rand there are banks of conglomerate inferior to the main reef. Thus, when on a previous page the section of the strata north of Johannesburg, towards the farm of Doornfontein (Fig. 2, Plate XXII.) was described, the reader will remember that there, amid the quartzites, were great masses of conglomerate visible along the whole southern flank of the Geldenhuis Valley, and running on with a few very evident dislocations in the direction of Rietfontein. No doubt, therefore, that the reef recognized and worked up to the present on the Rietfontein claim alone, belongs to this formation. This Rietfontein or Du Preez reef, as we shall see, is very thin and irregular, and one can understand how it is that, exploration-work having been brief and hasty, the further course of the reef has not been carefully traced out.

At Rietfontein, the complete section of the strata includes three reefs which are from north to south (that is, from roof to floor, since all the beds dip south) as follows:—

Firstly, the north reef worked only in the western shaft, No. 7, is a true band of conglomerate, of thickness varying from 6 to 12 inches, and sometimes, though seldom, as much as 40 inches thick. At the base, there is often a layer of crystalline pyrites, 1 inch or so thick, in dodecahedral groups, $\frac{1}{10}$ inch in diameter. This north reef has hitherto been very little worked at Rietfontein: it shows a curious

relationship with certain porphyrite-masses occurring on either side, but more especially northward. These porphyrites, no doubt, join up westward with those recorded at the Doornfontein farm.

About 50 feet farther south one meets with the main reef of Rietfontein, which includes two veins, known respectively as the middle reef and middle reef leader. In order to facilitate mining operations, the working-face is made 3½ to 5 feet high: here the hewers bring down a mass of very white quartzite, in the midst of which are either two thin strings of pebbles, or two pyritous streaks, the more difficult to follow up in the semi-darkness of the mine that the pebbles are white like the matrix. It is with these pebbles that the auriferous pyrites, often in the crystalline form is associated, and on their surfaces that it is encrusted. The somewhat unique and at all events extremely curious appearance of this ore calls vividly to mind that of certain beds of quartzite metamorphosed into quartz, such as Dr. Barrois has traced out amid the granite of Britanny. Only here and there do the streaks of conglomerate with little pebbles about ¼ inch across attain a thickness of 2 inches or so, and thereby it has been possible to recognize the reef at the outcrop. As one approaches a dyke the hue of the rock seems to darken.

Very often along this reef the results of sliding or slipping become perceptible, owing to the presence of talcose and schistose *débris*, which are more especially abundant in the foot-wall of the reef: a little gold, visible to the naked eye, is sometimes found deposited upon these at the contact with the reef. Often, too, one notes in the foot-wall of the reef, a vein of white quartz running between two schistose laminæ: this helps one to follow up the reef, although the quartz-vein does not always retain its parallelism with the reef, but sometimes runs up into the hanging-wall. Such phenomena as these are frequent in the Rand, where similar clayey *débris* with quartzose segregations are especially abundant in the foot-wall of the main reef leader.

Lastly, in the south there occurs a great mass of conglomerates, 50 to 65 feet thick, the interest of which is that, being the only reef visible at the surface, it nevertheless serves as an indicator for the thin reef situated at its hanging-wall. It is formed of small pebbles, and does not give a tenour of more than 3 or 4 grammes of gold (per metric ton). This reef is known as the stable reef, and is banked up southward against thick beds of quartzite, which form a continuous ridge from Rietfontein to the Geldenhuis district.

The Rietfontein mine is divided into two distinct districts, between which is a wholly unexplored zone. In the older mine, to the east, the

bed beginning with a dip of 50 degs. at the outcrop flattens soon to 20 degs. at the sixth and seventh levels. In the western mine the dip is still 50 degs. at the third level, but it soon decreases also in depth.

The whole of this neighbourhood is one of the most disturbed areas in the Rand, a circumstance which does not tend to make it easier to follow a thin band already very difficult to trace up. Moreover, the band, being very flat, is sometimes thrown out for a considerable distance by longitudinal faults, but the ore in it is often extremely rich.

About 1½ miles south of the Rietfontein reef, one finds along the whole extent of the Rand the important and well-known Main Reef Series, in which the chief workings lie, and which we will now deal with. From north to south, or from floor to roof, the reefs worked in this series are the following :—The main reef, comparatively poor, 23 to 26 feet, rather neglected at first, but now being attacked pretty well everywhere ; then the main reef leader (often very close to the main reef) and the south reef, both as a rule thin, varying from 1 or 2 to 40 inches—these two constitute the most reliable source of the wealth of the Rand. There are besides many unworked reefs, such as a north reef under the main reef, and a middle reef between the main reef leader and the south reef.

If one wishes to follow this series from end to end, as, for example, from west to east, in order to note its successive modifications, one is a little embarrassed as to where to begin. For in the whole of the Western Rand the correlations are of the most theoretical description, and the line, which on all the maps joins the homesteads of Middelvlei, Randfontein, and Luipaardsvlei together, is as yet hardly determined with anything approaching certainty. For instance, there is nothing to prove that the reef struck at some points on the Randfontein property really belongs to the Main Reef Series. Mining activity only begins to be well developed at the West Rand mines, at the George and May: then there is a break till one reaches the Champ d'Or ; at this mine, too, the reef which is being worked may be altogether a different one from the main reef. After this a great fault throws back the reefs far southward towards the Princess Estate and Durban Roodepoort, where one at last enters upon the continuous zone of the Rand. For the present we will leave aside, therefore, all this western end, but it will be referred to later on when we come to study the Buffelsdoorn reefs, which perhaps form its extreme limit.

Let us take, for example, the Durban Roodepoort district. The south reef presents there fairly constant characters from one mine to the

next. It is almost invariably extremely thin, not more than 2 to 3 inches (but in working it is found necessary to bring down a thickness of at least 2½ feet); and sometimes it forms a mere string of pebbles, which is considered rather as an indicator of rich ore. Experts generally admit that it is the poorer (even as regards absolute tenour) the more it widens out. On the other hand, miners prefer the points where the string of pebbles of the south reef is clearly differentiated from the encasing sandstones (which are the same both at roof and floor) to those where it seems to gradually shade off into the sandstones. Another good indicator appears to be the presence under the reef of a steatitic layer with spots of rust. As regards the rusty spots, their occurrence is easily explained, since they are correlative with the abundance of pyrites which itself includes the gold. As to the steatitic layer, which plays the part of a salband, and is doubtless the result of mechanical friction, its enriching influence (if such influence there be) may well be of the same order as that which one would ascribe to a shaly junction, *i.e.*, it would form a natural plane of percolation for underground waters.

The thinness of the reef, and the existence at its floor or foot-wall of a series of similar but smaller and poorer reefs, cause a good deal of difficulty in practical working. This ore is so hard to distinguish below ground from the encasing rock, that the miner is compelled to bring to bank and sort in the open light of day all the rock hewn down from a working-face 2½ feet high.

A sample section of the south reef may be taken, as follows, in descending order, from the fifth eastern level of Block 2 of the Durban Roodepoort mine (western end of the entire group of claims now under consideration):—

	Ft.	In.
Discontinuous micaceous shaly layer		
Sandstone	2	0
Bed with flattened pebbles passing into the overlying sandstone, with a tenour ranging at times up to 300 grammes of gold per metric ton	0	2
Sandstone containing now and then a little gold	0	2 to 0 8
Discontinuous clayey layer		

In some cases the pebbles which mark the south reef, instead of being localized in a mere string, are scattered over a thickness of 4 to 5 inches (all the gold being in the lower part); in other cases, the rich reef is overlain by a seam of poor conglomerate, 3 inches thick, divided by 4 inches of sandstone from the rich band.

At certain points in the mine, particularly at the seventh western level, are micaceous quartz-veins, which we must, do[illegible]gard as [illegible]gation-veins.

Farther east, in the eastern mine of the United Main Reef Company (Blocks 1 and 2), there is worked, as being the south reef, a sandstone with a few pebbles scattered about in it; height of working-face, 2 to $2\frac{3}{4}$ feet. At its base is a thin seam of conglomerate or foot-wall leader, with closely packed small pebbles, about 1 inch in diameter, without much pyrites. Most of the sandstone is passed over with the conglomerate to the stamp batteries, for it also contains a little gold; but it is reckoned that 70 per cent. of the gold at least comes from the basement conglomerate.

Sometimes at the hanging-wall of this conglomerate is a quartzose vein with green chlorite.

It should be noted that about 10 feet on either side of this reef occur two other reefs almost identical in appearance but poor, wherewith the rich reef might be easily confounded. Perhaps these three thin reefs are analogous to the three veins into which the south reef habitually splits up in the Central Rand, and especially in the east, as, for example, at Modderfontein.

We enter the rich zone of the Central Rand on quitting the Langlaagte estate; it includes the following mines:—Crown Reef, Johannesburg Pioneer and Bonanza, Robinson, Worcester, Ferreira, Wemmer, Salisbury, Jubilee, Village Main Reef, City and Suburban, Meyer and Charlton, Wolhuter, Spes Bona, George Goch and Metropolitan, Henry Nourse, New Heriot, Jumpers, Treasury, Geldenhuis Estate, Simmer and Jack, etc.

At the Crown Reef mine, the main reef, 10 to $13\frac{1}{2}$ feet thick, is just as in the Langlaagte estate, contiguous to the main reef leader, from which at times it is not even divided by a streak of sandstone. But from the industrial and practical point of view the two are carefully distinguished one from the other. The leader, some 16 inches thick, gives 30 grammes of gold per metric ton in the assays, while the main reef, at the many points where it has been struck, seems so poor (as a rule assaying 6 to 7 grammes) that it is scarcely ever worked.

Between the main reef and the south reef, a middle reef (assaying 5 to 6 grammes) is not worked at all.

The south reef, separated from the main reef leader by about 100 feet of quartzite, is made up of several strings of pebbles, remarkable for their flattened condition and scattered over a total height of $6\frac{1}{2}$ feet. The richest portion is, as usual, at the base. By a frequently recurring

phenomenon, there occurs at the foot-wall of this reef, for a distance of rather less than 200 feet, a quartz-vein about 6 inches broad.

From the point of view of the "aspect and habit" of the beds, this mine possesses two extremely characteristic features: a great longitudinal dyke (of which there are several other examples in the Rand, such as those at the Ferreira and East Rand mines, etc.) cut by the workings at the fifth level, and a central block let down between two faults.

The reefs seem to maintain in part the same character as one follows them southward to the Crown Deep mine, where, perhaps, they also partake of the distinctive features observed in the Robinson mine; to which reference will be made later on.

At the Bonanza, a comparatively new mine, started only in May, 1894, the main reef, as in most other mines, appears to be workable only in isolated portions. Its thickness varies from 2 to 16½ feet, with often an intercalated bed of sandstone. At some points it is separated from the main reef leader only by a thickness of 2½ feet, and at others the intervening beds are more than double that thickness.

The main reef leader, upon which, so far, not very much forewinning has been done, is in places extremely rich. Thus, at the third western level, it assays 45 grammes of gold per metric ton for a thickness of 39 inches. Between it and the south reef, which constitutes the chief wealth of the mine, there intervene about 165 feet of barren strata. The south reef conglomerate is said to be 4 feet thick, but it is then made to include several intercalated seams of sandstone. Thus at the third level, which is much the richest, and where consequently the workings have been most actively pushed on, the section is:—

	Feet.	Inches.
Conglomerate	2	0
Sandstone	0	8
Rich conglomerate (assaying 60 grammes)	0	2½
Sandstone	0	4
Gold-bearing conglomerate (assaying 10 grammes)	0	2

These are doubtless the same three seams of auriferous conglomerate that one meets with pretty well everywhere in the south reef. An interesting phenomenon, but much more widespread than is commonly believed, is the tendency of the intervening beds of sandstone to considerably increase or diminish in thickness within a very short distance. Sometimes, even with the almost complete disappearance of these sandstones, one gets an auriferous conglomerate nearly 8 feet thick.

Besides these workable reefs one meets with secondary valueless reefs, the so-called bastard reefs, both at the hanging-wall and foot-wall of the south reef.

Dykes and faults are fairly numerous here, as they are throughout the Central Rand.

The Robinson mine is the oldest known on the Rand for rich ores, and it is particularly interesting to note that at the deepest levels so far attained the miners appear to have struck an especially rich zone. From this it would not, of course, be permissible to conclude that there is a law according to which the reefs grow richer in depth, but it proves at any rate that they do not by any means become poorer.

This is one of the mines where the main reef is most actively worked. It is generally attacked at the same time as the main reef leader, which is separated from it by a foot or two of barren strata. Below the leader, and divided from it by a little sandstone, is a clayey salband. The leader itself varies up to 4 feet in thickness. The south reef has a breadth which may vary in the same level (the eighth) from 5 inches to 4 feet.

At the Ferreira mine, the south reef alone was worked for some considerable time, as being the richest bed in all this central portion of the field. But for some little time past the main reef leader has been actively attacked, and they are beginning by slow degrees to work at the main reef also.

Whereas in some places the main reef leader and the main reef are separated by a mere streak, in others the barren intervening band is 12 to 24 inches thick.

The south reef here is made up of two bands of conglomerate, whereof the richer is, at the base, separated by a sandstone which was formerly always picked out and cast aside as barren. This went on until quite recently, when people suddenly found out that it would yield assays up to 25 grammes of gold per metric ton.

When one studies the variations of the average assays at different levels, calculated in accordance with the results obtained from the workings during the past few years, it becomes plain that they follow no supposititious rule of progressive enrichment or impoverishment in depth. Thus, for instance, the tenth level of the south reef has proved to be the richest known up to the present.

At the Wemmer mine, the interval between the main reef leader and the main reef which, on the whole, is shown to be almost invariably very

small in the mines to the westward, has a tendency to increase enormously, and this change takes place rather suddenly along a great fault east of the Ferreira mine.

One finds, moreover, very closely comparable variations of thickness in the reefs. At the eighth western level the south reef widens out within a few feet from 1 inch or so to nearly 4 feet (with assays showing up to 3,000 grammes of gold per metric ton).

The main reef at the Wemmer mine is generally considered poor, and as not worth the cost of working (assays showing from 4 to 15 grammes per metric ton).

The main reef leader often contains here masses of milky-white rounded pebbles, closely packed together. Sometimes it assumes the aspect of the south reef, which is characterised by its flattened and apparently laminated pebbles.

In the Salisbury mine, the main reef and its leader are, as in the Wemmer, divided by a mass of quartzite, which is sometimes as much as 60 or 70 feet thick. The main reef—not worked so far—seems to be about 4¼ feet thick, with sandstone in the middle. At the fifth level it is succeeded by a long seam of quartz 3 to 4 inches thick.

According to the company who work the mine, the main reef leader yields the following average assays:—

	Thickness. Inches.	Grammes per Ton.
Third level*	10	87·90
Fourth level	16	64·55
Fifth level	9	81·80
Sixth level	13	45·45

At the sixth level, the horizontal distance from the main reef leader to the south reef is 82 feet.

As to the south reef, it comprises, as a rule, two rich portions—one at the foot-wall, and the other at the hanging-wall—the foot-wall leader being 12 inches thick, and the hanging leader over 6 inches thick, between which is a bed of quartzite, which attains a thickness of 3¼ feet at the eighth level. As usual, the foot-wall leader is the richer of the two. The general appearance of this reef is very dark: pebbles in it are few, and very sparsely scattered, even in the richest portions. The average assays from the south reef are as follows:—

* The levels are generally 100 feet apart, following the dip of the reef, or 50 to 80 feet in vertical distance.

	Thickness. Inches.	Grammes per Ton.
Third level	7	195·30
Fourth level	12	56·25
Fifth level	15	23·25
Sixth level	21	76·15
Seventh level	13	82·80
Eighth level	24	42·30

From this table one is enabled to judge in what measure is correct the hypothesis according to which a reef is richer the thinner it is, and *vice versa*. It is true that the maximum assay here corresponds to the smallest thickness, and similarly the minimum assay to the greatest thickness; but the rule will not fit the other levels. Similarly, in the main reef leader, the two highest assays correspond to the two least thicknesses. We must not, however, seek to apply this law too rigorously.*

Here the dip of the reefs is 80 degs. at the surface, 55 degs. at 617 feet vertical depth, and only 42 degs. at 928 feet.

In passing from the Salisbury mine to the Jubilee, a considerable fault is met with. Immediately east of this fault, the main reef and the main reef leader, which had diverged from one another by as much as 60 feet in the Wemmer and Salisbury mines, come together again. This circumstance is advantageous from the miner's point of view, because it decreases considerably the cost of hewing the main reef.

The main reef reaches in the Jubilee mine the great thickness of 13 to 16, sometimes 26 feet, but the assays barely show more than 7 to 9 grammes per metric ton. It must not be thought that one and the same bed of conglomerate makes up this entire thickness, which is what one might well imagine to be the case with all the mines on the Rand if one trusted to the managers' reports. There are invariably sandy intercalations in the central portion, and one particular band of sandstone is generally over 16 inches thick. The richest part is at the base.

In this mine the main reef leader is the richest reef, and it has an average thickness of $3\frac{1}{4}$ feet. Here and there it branches into two beds of 6 inches thickness, parted by quartzite $1\frac{3}{4}$ feet thick. At the base is a clayey salband containing a small quartz-vein.

The south reef varies here in thickness from 12 inches to 10 feet, with average assays ranging between 18 and 21 grammes, but at times reaching 60 grammes per metric ton.

* The necessity of caution in the matter will be still more clearly understood on inspection of a plan of trials and assays, such as that reproduced in Figs. 29 and 30, Plate XXV.

The Village Main Reef mine works the deep levels of the Wemmer, Salisbury, Jubilee, and City and Suburban companies, and therefore the reefs exposed in it present features analogous to those already described. It will suffice to note that, as at the Jubilee mine, the main reef and the main reef leader are generally close together.

At the Henry Nourse mine the beds become almost vertical, and show, therefore, quite unique features. The reefs struck here are:—The main reef (not worked), the main reef leader (termed middle reef), and the south reef (26 feet distant from the leader), which is the richest of the three.

The main reef leader is extremely irregular as to thickness, varying between 1 and 16 inches, but it is considered to average 12 inches. Here and there a curious feature is noted: the pebbles being less strongly cemented to the matrix, making less of a homogeneous mass with it than in the south reef, the fractured surfaces of the conglomerate instead of being plane-surfaces (which is always the case with the south reef) show the unbroken pebbles projecting from the matrix, as these have not been carried away with the broken-off portions.

The south reef has in some sort a schistose appearance, especially when it is so thin as in the third western level (6 to 10 inches). Elsewhere it thickens up to 5 feet or more and splits into three: a trifurcation already noticed in the Western Rand at the Bonanza mine, and recurring again in the Eastern Rand at Modderfontein.

At the New Heriot mine (now including the Ruby property) the beds are, like those at the Henry Nourse, all but vertical at the outcrop, having a dip of 80 degs. or thereabouts. Deeper down the dip decreases to 45 degs. Here, again, it is found difficult to correlate the reefs, and this difficulty increases as one goes farther eastward. The reefs, on account of their high dip, come very close together in horizontal section, and as they bifurcate or run across each other pretty often it is no easy matter to follow them up—the less easy that no great care seems to have been expended on studies of this kind.* A cross-cut made at the third level has revealed the existence of ten distinct reefs, three or four of which are alone worked (four west of that level, but this may be merely because one of them has split into two).

* Sections such as that reproduced of the Simmer and Jack (Figs. 23 to 27, Plates XXIV. and XXV.) show how easy it is to fall astray in the correlation of these reefs, which constantly bifurcate, nip out, broaden out, and alter in character, unless one studies very attentively the strata, more especially where they have been dislocated by a fault.

At the Witwatersrand mine (formerly known as Knight's), the reefs which were very slightly inclined on the convex portion of their curvature, east of the Geldenhuis and west of the Simmer mine (see Fig. 8, Plate XXIII.), resume a high dip of about 60 degs. on the concave portion.

In this area there is abundant evidence of earth-movements posterior to the deposition of the rocks, and especially of slipping of strata one over the other, with the formation of clayey and shaly salbands, along which quartz-veins have frequently segregated. One meets also with great longitudinal dykes, well marked in the Witwatersrand and the East Rand mines. Possibly we should ascribe to some mechanical agency of the kind, causing a repetition by folding of the Main Reef Series, the appearance in this zone north of the series of a practically identical though poorer series. On the other hand, it may be that we are dealing with two really distinct series: this is a point which will need to be enquired into. Finally, as the last feature of general interest, we may note the presence, below the reef, of a band of mica-schist or laminated quartzite, which possibly corresponds to the bed so highly developed to the eastward in the Van Ryn and Modderfontein district.

In the mines belonging to the East Rand Company (Driefontein, Angelo, New Comet, Agnes Munro, Cinderella, and New Blue Sky) one may follow practically from end to end two reefs. These are the main reef or north reef (already met with in the Witwatersrand and Balmoral mines), and the south reef (as at Ginsberg).

The north reef is struck along a line 3½ miles in length, and is very extensively worked in the New Comet mine. The south reef, followed up in the same manner by the workings, had been lost sight of under the superficial deposits east of the New Comet. But in September, 1895, it was struck once more, at the depth of 594 feet, by a boring in the corner of the Cason Black property, near the Cinderella mine. Its prolongation from one end of the company's properties to the other may therefore now be regarded as assured.

Beyond the East Rand, there is a considerable gap in the series of outcrops, corresponding to the Apex mines and the Benoni, as far as Kleinfontein and Van Ryn. There, indeed, as at the East Rand, the surface of the soil is entirely masked by thick clay-deposits, sometimes too, by fragments of Karoo Beds denuded away by the same denuding agent as that which left the clay as a residue. For want of borings, one is in much the same predicament as people were at the East Rand until recent exploration-work allowed of the reefs being determined. How-

ever, it appears that in the Western Kleinfontein property which occupies a portion of the Benoni farm, the north reef of Kleinfontein and Van Ryn has been struck. It is moreover possible, guiding oneself by the outcrop of the Kimberley reef, which lies south of the main reef, and is always easier to follow up, to conceive the existence of a curve or contour diverting the beds northwards with a north-easterly strike, which they then retain up to Modderfontein, and also the existence of a fault with a horizontal throw of about 5,000 feet towards the south-east.

After this we come again to a belt of workings which includes the mines of Kleinfontein, Van Ryn, New Chimes, and Modderfontein—this belt is continued by prospecting works through the Modderfontein Extension, Klippfontein, and Amatola properties.*

At Kleinfontein two well-determined reefs are worked: the main reef, and at its hanging-wall a reef locally termed "south reef," but which must in reality be the main reef leader. The true south reef corresponds probably to that actually worked at the Modderfontein and Van Ryn mines to the east, just as at the East Rand to the west, but which has not yet been taken advantage of at Kleinfontein.

This is the first property whereon we may note in its full development a phenomenon which going thence eastwards plays a highly important part, as it does also more to the south of the Nigel and Heidelberg mines, namely, the existence of a bed of shale on the footwall of the main reef.† It is true that in the preceding pages attention has been repeatedly called to the clayey and sometimes shaly streaks which are often found beneath the main reef leader, and which develop into true shales at the Witwatersrand mine. But we are now going to deal with thick and well characterized beds of these shales.

At the Modderfontein mine the section is as follows in descending order :—

Kimberley reef	—
Quartzite	1,300 feet.
Bird reef	40 to 50 ,,
Quartzite, often a little micaceous at the foot-wall	1,000 ,,

* West of Kleinfontein some prospecting work has been done on the main reef, in the Benoni, Western Kleinfontein, and Chimes West properties.

† These shales, wherein now and again a little magnetite occurs, are perhaps the same shales as those of Hospital Hill, previously described. The latter lie between the Main Reef Series and the Rietfontein reef, that is to say, that they, too, are at the foot-wall of the main reef, although in the Central Rand they are separated from it by a considerable thickness of quartzites.

South reef—	
Hanging No. 2 (not worked)	4 inches.
Quartzite	16 to 20 ,,
Hanging leader (rich)	3 to 4 ,,
Very hard black quartzite	24 to 40 ,,
Middle reef	1½ to 2 ,,
White quartzite	24 to 40 ,,
Foot-wall leader	3 to 4 ,,
Laminated schistose bed	—
Quartzite	80 feet.
North leader	3 inches.
Quartzite	160 feet.
Main reef leader	6 inches.
Quartzitic sandstone	33 to 40 feet.
Main reef (north reef)	40 inches.
Chlorite-schists	250 to 300 feet.

The chlorite-schists which form the foot-wall of the main reef are often much dislocated. The main reef which lies above them (and the extensive workings in which, at the Van Ryn mine to the westward, have already been mentioned) formerly gave rise east of Modderfontein to a few unsuccessful attempts at working. Towards the east the main reef runs on to Modderfontein, with the same characteristic foot-wall of schists, 24 to 36 inches thick, and at 4½ feet distance from the hanging-wall a thin leader of 6 inches.

The north leader of the south reef, which also gave good results at the Chimes mine, has, so far, proved unworkable at Modderfontein.

The south reef, properly so-called, to which on the whole the workings in the last-named mine may be regarded as confined, is made up of a group of twelve or fifteen small seams of conglomerate, extremely thin and very difficult to distinguish one from the other, the more difficult that the richness in gold appears to pass from one seam to the next. Three of them only are worked continuously: the foot-wall leader, middle reef, and hanging leader. These seams, very different indeed from the majority of those conglomerates which we have so far been dealing with in the Rand, are, as aforesaid, very thin (1½ to 4 inches), with little pebbles, variously glassy white, smoky, dull black, or pinkish—which have a look of having been crushed, and show little pyrites. The richest seam of all is the hanging leader. The very hard black quartzite which overlies it is rather coarse grained, and by reason of that fact always contains a certain proportion of gold (7 to 9 grammes per metric ton) and therefore is crushed in the stamp-batteries. At the surface it assumes a chocolate-brown tint with green spots. The middle reef is very thin and frequently disappears, like all the Modderfontein

reefs, as well as a fault-line, which appears to follow it. Finally, the foot-wall leader is, as a rule, poor and very irregular; it appears to become richer at the lower levels, at the same time as it approaches the black quartzites.

The dip is here frequently very high in the western portion of the workings, almost exactly the same as in the Chimes property near by, where it reaches and even exceeds 78 degs. One notes in this nearly vertical reef practically horizontal veins of barren white quartz. In depth the dip decreases from 78 to 60 degs. Going eastward, the beds flatten to dips as low as 25 or 20 degs.

Judging from the results yielded by the assays, the manager of the mine estimated that when crushings on a large scale should begin (in February, 1896) the average tenour would be 21 to 23 grammes per metric ton, of which 13 to 15 grammes would be got by amalgamation.

Beyond Modderfontein workings cease, and as the strata are very much concealed, either by drifts or Karoo Beds (Coal-measures), and as, moreover, the surface of the country is very flat and frequently marshy at the outcrops of the reefs, exploration-work progresses with great slowness. Nevertheless, one may even now follow, across the Modderfontein Extension, Klippfontein, and Amatola properties, the presumable course of the north reef (main reef), characterized by the mass of shales underlying its foot-wall and the two overlying reefs (bird reef and Kimberley reef), whose outcrops are always better marked than those of the main reef. This localizes very conveniently the zone of research for the south reef, even in the vast areas where it has not yet been struck.

The bird reef, which in transverse sections is divided from the south reef by about 1,000 feet of quartzites, is in reality much more distant from it at the outcrop, for the beds in all this area are, comparatively speaking, horizontal (dip only 20 to 25 degs.). The bird reef is 40 to 50 feet broad, and is characterized by masses of small white pebbles (very few black) strongly cemented in a very hard matrix. It passes under the Kaffir compound at Modderfontein, where it exceptionally contains a little visible gold. But hitherto it has proved everywhere to be valueless, although in the west of the Rand a reef which is assimilated to it has formed a pretext for promoting sundry companies.

Some 1,300 feet south of the bird reef an enormous mass of pudding-stone crops out, some portions of it containing gigantic pebbles: this is called the Kimberley reef, and is the better recognized in this area that it occupies quite a considerable surface, being all but horizontal. It

presents equally distinct features along the whole length of the Rand, and has generally been regarded as poor, the barren pebbles being so big that they have left no room for an auriferous cementing-material or matrix. But in the thickness of the conglomerate one sometimes meets with seams of smaller pebbles, highly charged with pyrites. In some localities these have recently given rise to expectations, for the fulfilment of which we must still wait. It is seams of this kind that some persons are trying to work at Rip (near the Champ d'Or mine), where they closely approach the reef there regarded as the main reef. South of Roodepoort, they recur in the Marie Louise property; and, again, south of the East Rand, at the St. John mine, where they have formed the object on various occasions of more or less precarious mining enterprise. Finally, some companies to whose names no particular reference has hitherto been made, as their existence is up to the present purely theoretical, such as the Kleinfontein Deep, etc., have been promoted with the object of exploring these seams.

The prospecting-work on the Modderfontein Extension and Klippfontein properties has, so far, only reached the main reef (recognizable from its foot-wall of shales), where it is gritty and somewhat poor. This may be only a rather unhappy mischance, but it may also imply either the presence in this area of a poor belt (such as we have already seen to occur in certain parts of the Rand) or definite impoverishment and sterility; for it is plain that, however extensive the auriferous impregnation of the conglomerates may have been, it must stop somewhere.

As to the south reef, it has certainly been struck on the Klippfontein property, where it is well characterized by a group of thin seams with small pebbles and intercalated quartzites; but it is not yet known which among all these are the rich leaders, if rich leaders there be.

It is interesting to note that the reefs preserve up to this point—that is, considerably beyond the spot where the old maps indicated correlation, by means of an hypothetical north-and-south contour, with the Nigel reef, and sketched here the boundary of the basin—a north-easterly strike. There would be little cause for surprise if, one of these days, it was found that this general direction holds good, excepting merely local interruptions, for a considerably greater distance.* The writer believes, indeed, as before stated, that we are not dealing here with a restricted lacustrine

* It is a subject for regret that all the prospectors in this district, finding it extremely convenient to let their neighbours do the searching, and cut in afterwards to reap the fruits of other men's work, progress at so slow a rate, and make, on the whole, so feeble a display of energy.

deposit, but with a synclinal depression brought about by folding in a very extensive conglomerate formation. This synclinal, like all folds of similar character, which are so well exemplified in the Alps and the Jura, is probably prolonged with various flexures and extensions, and so the study of this area has considerable theoretical as well as practical interest.

It is true that the arenaceous facies tends here to predominate in the Main Reef Series at the expense of the conglomerates; and on the other side of the synclinal, in the Nigel Reef Series—which may very possibly constitute the repetition of the same series in the other limb of the depression—the rich reefs are similarly gritty, or contain only small pebbles; but the writer fails to see that any consequence can be drawn from it as regards the greater or less proximity of the shore-line at the time when these deposits were being formed, or, therefore, as regards the conditions under which the gold may have accumulated. We must not forget, indeed, that immediately above the hanging-wall are reefs with big pebbles, such as the Kimberley reef. This is probably a local phenomenon merely, due to the direction assumed by the currents in the waters wherein these sediments were being laid down—perhaps some tranquil backwater of the estuary formed by the mouth of a great river.

One word more on this subject will suffice. This Modderfontein and Nigel zone is that in which the two rims of the synclinal basin (assuming the correlation of the Nigel Reef Series with the Main Reef Series) are nearest to each other. If we notice, moreover, that the dip east of Modderfontein, as well as at the Nigel mines, is very low—20 to 30 degs. or so—it becomes easy to draw a section showing that the maximum vertical depth of the thalweg is about 8,000 feet.

This being an inaccessible depth for mining work, it appears extremely improbable that drifts driven from either rim of the basin will ever meet each other deep down. If, nevertheless, with the bold spirit of enterprise usually characteristic of the mining profession in South Africa, a bore-hole were put down at a vast depth in order to sound the bottom of the synclinal, the area under consideration would appear peculiarly suitable for the purpose.

About 20 miles south of Modderfontein we meet, as previously stated and repeated, at the Nigel and Heidelberg mines, a series of auriferous conglomerates dipping contrariwise from those just described in the Main Reef Series. They dip, that is to say, northwards, and are sufficiently similar to the Main Reef Series to make the observer plausibly infer that they are its repetition on the other flank of the synclinal. In this

district, so far, only one important mine has been worked, the Nigel mine. But attention having been drawn of late to the especially interesting character of the district, and the field there open to enterprise appearing all the more extensive that its limits are ill-defined, exploration-work has been actively pushed forward, and, perhaps, will allow of some pronouncement being shortly made as to the industrial future of the area.

At the Nigel mine the beds are nearly horizontal (18 to 23 degs. at the outcrop), and, perhaps, this horizontality will of itself be sufficient to explain why the contour-line marked out by the outcrop of one of them becomes, in consequence of a comparatively gentle undulation of the strata, a very marked curve: this curve would be hardly noticeable if the beds were dipping steeply. Reducing the phenomenon to a simple geometrical expression, we find here the section of a cylindrical surface by a plane making a very low angle with its axis: this produces an extremely elongated ellipse: whereas, with vertical beds we should have the section of a similar cylinder by a plane perpendicular to the axis producing an arc of a circle. At any rate, one notes that within the Nigel property itself the strata describe a well marked curve, clearly seen in the present mine-workings.

The reef worked at the Nigel mine is a band of conglomerate, generally rather thin (26 inches on the average) though it sometimes attains 40 inches, made up of rather small pebbles, generally smoky, and giving to the rock a greyish tinge,* with pebbles of dull black quartzite, now and then angular (like many found in the main reef), pebbles of yellow quartzite (rather peculiar to this mine) and abundance of pyrites. This reef overlies shales which now and then contain magnetite: that is to say, that its geological environment is comparable to that of the north reef of Kleinfontein, Van Ryn, Modderfontein, and Klippfontein, which has been in these pages correlated with the main reef. It is in the same way overlain by quartzites, and both in general aspect and thickness it differs little from the aforesaid main reef, which, as we know, thins out considerably in the east of the Rand.

True it is that these reasons hardly afford a sufficient basis for the correlation reef by reef at distances so great—the less so that the pebbles of the Nigel reef are generally much smaller than those of the main reef, wherever the writer has had occasion to observe the last-named. But it

* These pebbles are less than 0·40 inch in diameter on the average, but their dimensions are very variable, and they are very irregularly arranged (samples 1479, 1 and 2).

remains none the less a striking fact that one should find, so far from the outcrop of the Witwatersrand beds, a formation which, taken as a whole, is so entirely comparable with them and which appears to have undergone so little modification in this vast space-interval (as for instance, the recurrence of similar pebbles exclusively of quartz material, and the identity of mineralogical structure). This accords with an observation already brought to the readers' notice; it proves, namely, that the conglomerates, apart from their auriferous matrix, far from corresponding to a restricted lacustrine deposit in which (as may be seen in the Coal-measure lakes of the Central Plateau of France) the sediments continually vary in character from one point to the next, these conglomerates, the writer asserts, are in reality the result of a phenomenon infinitely more extensive in scope, more widespread, and more regular, such as marine sedimentation.

It would be absurd to assume *a priori* that wherever these conglomerates may recur with analogous characters there they will continue to be gold-bearing. But if there be really a junction deep down between the Johannesburg series and the Nigel-Heidelberg series, the presence of gold on both sides of the basin lends some plausibility to the theory of its continuance in the intervening space in greater or less quantity, that is to say down to the deepest parts which workings are ever likely to reach—for the sides of the basin at the time of the introduction of the gold had nothing special about them as a congenial resting-place for the ore, and the outcrops that we now see are merely the consequence of later folding and erosion.

The Nigel reef, as regards tenour in gold, is especially rich at some points, but is in this respect extremely irregular. One may, for instance, find in it rich shoots 3 to 33 feet broad, with very poor reef on either side. And then it frequently happens that in the portions nearer the surface the reef is very poor, but becomes richer at a certain depth. Thus at shaft No. 3 the ore only pays at about 100 feet below bank, and at shaft No. 12 only at about 330 feet below. At the time of the writer's visit to this mine, in this same shaft No. 3, at the eighth western level, tenours of gold of 2 kilogrammes to the metric ton [1 in 500] were found over a breadth of 10 inches, whereas the assays yielded poor results from the fifth and tenth levels. The whole aspect and the very richness of the bed recall rather the south reef than the main reef of the Rand.

The reef can be followed along the strike for a distance of about 4,000 feet by means of twelve shafts 330 feet apart, and the portion which

shows the greatest constancy in richness is about the middle, at shaft No. 7. The writer has endeavoured to ascertain whether there is some "law of centrifugal impoverishment" of the reef, but has not been able to establish any such law from the evidence obtained.

Exploration throughout the Heidelberg district is complicated by two difficulties which are not met with in the Witwatersrand properly so-called. On the one hand, the beds being nearly horizontal, their intersection with the surface describes very marked sinuosities, and may perhaps bring about several recurrences of the reef in successive valleys. The general geology of the region not having yet been mapped out in sufficient detail, it requires very prolonged study in order to correlate with each other the scattered fragments of the reefs. Here and there, workings have been started on these separate fragments, and at each point the miners think that they have struck the Nigel reef.* On the other hand, this reef being very thin and lying between rocks so sharply contrasted as shales and quartzitic sandstones, it has happened over and over again that the erosive action of surface-waters has been brought to bear at the junction, originating a sliding of the hanging-wall over the foot-wall. By this sliding motion the entire reef has been laminated, and has disappeared at the outcrop.

The writer himself ascertained in certain headings boldly driven into the supposed *locus* of the reef—that is, at the junction of the shales and quartzites, at a point where no conglomerate appeared at the outcrop—that one sometimes ended by finding the conglomerate in its proper position some 100 or 170 feet below ground. Thus it is that throughout the Heidelberg district one is induced to look first of all for the conglomerate along the line of junction (alone visible) of the shales and quartzites. After which preliminary operation, the missing conglomerate being found, one has next to prove its richness in gold.

Before passing on to other reefs higher up in the series, such as the Kimberley or the black reef, let us return for a short space to the western part of the Rand, in order to study a few deposits which have been purposely left aside so far, and which on the maps are joined up by a purely theoretical line with the Main Reef Series, as far as Potchefstroom and Klerksdorp.

* Thus in the accompanying map (Fig. 5, Plate XXII.) two reefs are drawn south of Heidelberg, one of which the writer was enabled to follow for a considerable distance along the Biesbok Spruit, and the other, which Mr. Goldmann has preferred to correlate hypothetically with the Nigel reef, runs towards Molyneux and Blinkpoort.

On this side, one passes first through the Luipaardsvlei, West Rand, and Champ d'Or properties. Beyond Luipaardsvlei to the westward one may note—if not by the Main Reef Series, all trace of which disappears, at least by the country rock, and especially by the invariably well characterized bird and Kimberley or battery reefs—that the reef series as a whole makes a sharp bend, and strikes north-and-south (a strike ascertained at Randfontein). After which, across the farmsteads of Middevlei, Hartebeestfontein, and Witfontein, the old strike seems to be resumed. What becomes of the series afterwards we do not yet know, but on looking at a general geological map, such as that drawn up by Messrs. Draper and Wilson Moore, in Mr. Goldmann's work, one is enabled to form some idea, even though the map may not be very exact in its details. The reader will note in the accompanying map (Fig. 5, Plate XXII.), largely based on the above-mentioned work, that the quartzite-and-conglomerate series, after being thrown back by a so-called granite-dyke, forms a long anticlinal north-east and south-west ridge, overlain on both sides by the dolomitic limestones. (These latter may well mask the outcrop of certain formations, but they do not preclude the possible existence of these deeper down.) One comes in this way to the Buffelsdoorn area, where the mines are at work on an auriferous series comparable with that of the Rand, striking north-east and south-west and dipping east. It is with these workings alone that we now propose to deal.

In the first place, one will note that their position in the immediate neighbourhood of the overlying dolomitic limestone by no means coincides with the stratigraphical position of the main reef in the Rand. But, as the dolomite overlies the quartzites unconformably, this hardly constitutes a fatal objection to the oft-proposed correlation of the Buffelsdoorn reef with the main reef, for the dolomite may well come into contact with beds higher or lower in the series.

On the Buffelsdoorn Estate, the so-called white reef alone is worked. But, at 65 feet from the foot-wall to the north-west is another workable reef with gigantic pebbles, the north reef, and 400 feet farther on in the same direction we meet with a reef containing small pebbles, the red reef. To this reef great importance is attached on certain neighbouring properties, although none of the evidence so far available appears to justify that opinion. About 100 feet south of the white reef is another reef with big pebbles, but valueless; then comes an unmistakable ridge of quartzite; and about 4,000 feet farther yet is an all but horizontal reef, which is correlated with the black reef.

The white reef in the present workings at Buffelsdoorn has a very peculiar aspect, quite different from anything observed in the centre of the Rand; indeed, there is nothing at all, so far as the writer has seen, even analogous to it, except, perhaps, in the east, towards Modderfontein and Rietfontein. Even so, however, there are very considerable divergences. Instead of being a conglomerate, it is almost everywhere simply a quartzite, which at the first glance appears to differ in no respect from the encasing quartzites (although in the west it begins to include a few pebbles).* The result is that it is extremely difficult to follow up the ore in the mine, and mistakes are not infrequent in this connexion: barren rock is often worked, while comparatively rich portions are left untouched. One would think, nevertheless, that a more attentive and more scientific study of the ore—a study which hardly accords with the taste, and is, perhaps, beyond the capacity of most of the British engineers in the Transvaal—would lead to a more rational mode of working. Thus, on examining the auriferous quartzites of Buffelsdoorn, it is plain that the gold there, like everywhere else in the Transvaal, is associated with pyrites, and that this pyrites (though sometimes barely visible) concentrates along certain venules; or else, by a curious phenomenon, which will also be noticed at the Orion mine, the pyrites is very often accompanied by a carbonaceous black material, which did perhaps influence in some way the precipitation of the gold.† These pyritous and carbonaceous venules are arranged anyhow in the rock, not only parallel with the bedding, but transverse to it. They seem, however, especially abundant at the base of the quartzites, where at the same time a few sparsely-scattered pebbles are met with. When they are found elsewhere, it appears that they accompany a coarser sandstone, made up of more granular constituents than the neighbouring quartzite. At the foot-wall the ore-deposit seems generally rather restricted, but at the hanging-wall it passes gradually into barren quartzite. Its worked thickness is considerable, containing, however, large masses of absolutely barren rock, and often reaches 20 or 25 feet. It is crossed by quartz-veins, 3 to 4 inches broad, with fairly large crystals of copper pyrites, galena, blende, sometimes even gold, and clayey salbands—that is, they present some of the features characteristic of true veins, although they are probably the result of a simple segregation. The grade is low—some

* There does not seem any great improbability in the suggestion that the quartzite becomes a conglomerate a certain distance off.

† At Kongsberg, in Norway, anthracite is found under similar conditions in silver veins, which occur in the form of extremely narrow venules.

14 grammes per metric ton, according to statistics supplied by the company—but the results of the workings are still too incomplete to allow of anything definite being said in this connexion.

On the east, the Buffelsdoorn strata are stopped short very suddenly by a dyke of eruptive rock, which throws them back northward. Westward, they may be followed for a considerable distance in the direction of the Buffelsdoorn A, Buffelsdoorn Consolidated, and other mines. Deeper down, these strata are traversed, between the fifth and sixth levels, by a longitudinal dyke analogous to those of the Crown Reef, East Rand, and other mines. This is an exceedingly thick dyke, and the workings have only just been cut through it. At two points, in the eastern and western fifth level, the writer noted a considerable broadening-out of the reef along its contact with the longitudinal dyke, but this is probably a mere coincidence.

In order to complete our study of the auriferous rocks, it only remains to advert briefly to the secondary reefs lying to the southward, that is, on the hanging-wall of the Main Reef Series.

In crossing the main reef to go south, one meets, amid the quartzites which make up the great mass of the strata, numerous bands of conglomerate, which often contain more or less noticeable traces of gold. But this does not in the least imply that such gold as may be so found is workable there.

Among these southern reefs, reference has already been made by the way to the bird and Kimberley or battery reefs. Mention has also been made of the workings opened in the last-named at Rip, Battery Extension, and Marie Louise mines (south of Vogelstruis), as well as the part played by the dyke in regard to the prospecting-work on the Modderfontein Extension and Klippfontein properties.

In the west, this battery reef is met with again south of the West Rand mines, on the Violet property. It takes there a turn to the south, and is accompanied at the hanging-wall by a reef known as the Burgers reef. It strikes across the Rietvlei farm from north to south, parallel with the Randfontein reef.

Due south of Johannesburg, one meets—about 3 miles out of the town, on the Rosettenstein ridge, and above the racecourse—with an enormous mass of conglomerates, which have so far given rise to no important workings, and contain mere traces of gold. But these rocks are remarkable for the great abundance and enormous size of the pebbles of white quartzite which they contain.

A little farther south, one meets again with conglomerates in numerous very thick beds. On these the De Paaz mine was at one time started,* and almost immediately afterwards one comes to the great stretch of amygdaloidal diabases, which extend from west to east over a length of 20 miles and a breadth of 3,000 feet from the farmstead of Doornkop to Olifantvlei, Rietvlei, etc.

South of these eruptive rocks, and in many cases at the junction with the dolomitic limestones, occurs a very remarkable reef, often extremely rich. This is known as the black reef, and is worked at the Orion mine (Roodekop farm), and on the neighbouring properties (Minerva, etc.). It appears to be, without doubt, the same reef as that which occurs farther westward on the Steyn Estate and Madeline properties—where the results attained so far, however, appear to offer but small encouragement to prospectors—then again at the Midas mine, and perhaps even beyond Buffelsdoorn.†

The deposits at the Orion mine are of extreme interest from the geological point of view, and it is, therefore, proposed to dwell on them at some length. They differ in every respect from all the others, and we find here the spot where the part played by the driftage of pyrites and its sedimentation among the auriferous beds of the Rand are perhaps most clearly seen. The deposits appear also to be in direct relationship with the eruptive rocks, and as the locality is very near the axis of the great synclinal basin of the district, the very aspect of the beds, almost horizontal as they are, is highly characteristic.

The section is as follows:—At the base is a sheet of eruptive rock, with curious star-shaped aggregates of tourmaline which will be described on a future occasion. This rock is thrust between the sedimentary beds almost parallel with their strike: that is between the quartzites of the Rand on the north (at the foot-wall) and the quartzites directly overlain by dolomitic limestones (at the hanging-wall). It presents a series of extraordinary undulations of depressions and bosses lengthened out in an east-and-west direction: this is a possible consequence of the foldings of the rocks with which these are parallel. The result is embodied in a number of east-and-west shoots or channels, in which the ore has been palpably segregated, and thus on the number of these shoots the future of the mines is entirely dependent.

* This is the Elsburg reef (which takes its name from the village of Elsburg) and was at one time worked on the Aurum Company's property. Going from here to the Orion property one also meets with a big unworkable reef, 13 to 16½ feet thick, with enormous pebbles. This is known as the eagles reef.

† The correlation of the Eastleigh reef, south of Buffelsdoorn, with the black reef implies the bridging over of distances so vast that it must be regarded as purely theoretical.

The ore in the shoots, consisting of a practically compact mass of auriferous pyrites, is well-bedded (stratified). It is in no sense, at least in its present condition, a vein-deposit, for even with the naked eye one detects on every hand rolled pebbles of pyrites.* In fact, mechanical agencies have been unmistakably at work, as a natural consequence of the driftage by reason of which the zone, richest in gold, is always at the base —this position is quite independent of the structure of the ore, the latter being made up of rolled pyrites in grains of varying fineness, and the beds of big pyrites-pebbles may be observed to occur at the top as well as at the bottom of the section.† We have already noted on several occasions in the Rand some tendency of the gold to concentrate near the base, but here this tendency becomes a distinct characteristic.

This formation appears to call for some remark. On the one hand, the existence of rolled pebbles of pyrites 0·20 inch or so in diameter proves (when one considers the extreme friability of that mineral) that the pyrites has been hardly displaced from the spot where it was formed and chemically precipitated, and that it has simply been rolled by the waves almost *in situ*. This agrees very well with the general aspect of the few quartz-pebbles which play so insignificant a part here. They are white, black, or dark red in colour, and most of them are still very angular and of irregular shape, resembling far more closely the fragments of a breccia than a conglomerate. Pebbles, properly so-called, only appear on the periphery of these pyrites-filled depressions, and then the ore sometimes takes on gradually the facies of an ordinary conglomerate.

One may now well ask whether we have not here, under our very eyes, the effects of immediate *remaniement*, or mechanical modification of an auriferous pyrites-deposit chemically precipitated. This may itself have originated at the contact of the eruptive rock, as a consequence of the intrusion of that rock into the midst of the sediments in process of formation.

At all events, this sedimentation of the pyrites appears to have taken place subsequent to the folding of the eruptive rock (since it has been deposited in the hollows of that rock), and previous to the formation of the quartzites, which rest with great regularity, and all but horizontally,

* In the rocks at the outcrop whence the pyrites has, as usual, disappeared, the observer easily detects the round cavities left by the small pyrites-pebbles, instead of the angular hollows common in the auriferous quartz. The hypothesis has been put forward that the black reef may owe its distinctive form to the fact that it is merely the result of a re-sorting of the material of previously formed reefs. But the above hypothesis does not seem likely to hold the field.

† In addition to the rolled pyrites, there are zones of crystallized pyrites which may be in part the result of secondary action.

on the hanging-wall of the ore-deposits.* These quartzites themselves, about 65 feet thick, are almost directly overlain by black limestones, the first rocks of the kind that we have so far met with in the geological series in the area under discussion. The occurrence of these limestones points to a change in the conditions of deposition, and above them, in fact, gold ceases to be found.

It will be noted that such metals as copper, lead, cobalt, nickel, arsenic, etc., of which only a few traces were present in the ores of the Rand, as shown by chemical analyses, are here sufficiently abundant to deserve the attention of the miner.

To sum up, the Orion deposit consists of a certain number of shoots or channels running east-and-west, and filled with auriferous pyrites. This pyrites varies from white and shining to dark and dull, the latter appearance being considered the most promising, and is in masses, sometimes of very fine structure, and in other cases made up of rolled grains.

At the foot-wall of this pyrites, in the superficial oxidized belt, beyond which the workings have not hitherto penetrated, and which, by reason of the horizontality of the strata, will be found to extend for a considerable distance, there occurs, running alongside the pyrites, a thin vein of brown hæmatite, mixed here and there with shaly clay. This, no doubt, originated from the infiltration of surface-waters along the contact; and here the richness in gold attains its maximum—some assays yielding as much as 3 kilogrammes per metric ton [or 3 in 1,000]. This dark-coloured vein it is which has induced miners to give the reef the name of "black reef." Along this shaly band there often occurs graphitic carbonaceous matter which may well have played some part in the precipitation of the gold, and a similar occurrence has been already noted at Buffelsdoorn. It is possible that this action of the surface-waters may have brought about, along the hæmatite-vein, a certain amount of segregation of gold. Some observers claim to have noted that the ore is richest where the foot-wall rock is most decomposed: a phenomenon which very frequently is associated with the bottom part of synclinals.

Towards the south of the same area, beds of manganese dioxide are seen interstratified with the other rocks, and they have, too, the property of acting as channels to the surface-waters.

* It is said that in some of the black reef deposits the quartzites overlying the hanging-wall disappear. Thus it is asserted that at Eastleigh the reef has been struck immediately below the limestone.

C.—Special Description of the Gold Ores of the Witwatersrand.

So far we have been devoting our attention to the general aspect of the auriferous conglomerates of the Witwatersrand, and have not troubled ourselves with the structural details of the rocks. The time has now come to look into these a little more closely.

The gold ores of the Witwatersrand are, as we have already remarked, of a quite special type, which hardly resembles anything seen in the auriferous deposits of other areas.

Thus they are made up primarily of conglomerates and, quite secondarily, of coarse grits or quartzites, with more or less rolled quartzose constituents, cemented by a siliceous matrix, wherein are scattered small grains of quartz and which contains veins of pyrites—a mineral with which the gold always appears to have been originally associated.

The dimensions of the rolled constituents may vary enormously from one auriferous band to the next, and this question of size gives no reliable indication as to the richness of a reef in gold. Thus it is that we may get identical assays from a conglomerate with pebbles 2 or even 4 inches in diameter (as, for example, the Kimberley reef) and from an ordinary fine-grained quartzite (as, for example, the Buffelsdoorn reef). Nevertheless, in a given bed, corresponding to a particular period of deposition, and above all at a particular spot in this bed, it is possible to assert that almost without exception gold segregates in association with the biggest constituents, that is, with those whose displacement by the waves has necessitated the largest amount of force. This holds good with the conglomerates properly so-called, and also with fine-grained conglomerates and ordinary quartzites. Thus, on examining a gold-bearing quartzite such as that of Buffelsdoorn, it will be observed that the auriferous pyrites is preferably associated with those portions of the quartzite that are passing into coarse grit; and if a few scattered pebbles form ever so discontinuous a seam in the rock, it is along that seam that the auriferous pyrites will be found. Finally, microscopic examination reveals also a tendency of the pyrites and gold "beaches" to accumulate in the neighbourhood of the pebbles.

But a not infrequent occurrence, a few feet away from an ordinary quartzite, or from a small-pebbled auriferous conglomerate, is an absolutely barren band with big pebbles. Moreover, two neighbouring bands with pebbles of exactly similar size may differ greatly as regards their gold content. Of this fact the main reef and the main reef leader,

beds which are generally very close to each other, yield frequent proof. The main reef, with pebbles as big as—nay, often bigger than—those of the leader, assays almost invariably at a much lower grade.*

For the sake of omitting nothing, the auriferous quartzites have just been mentioned; but the ore which is by far of the most frequent occurrence, especially in the older mines of the Central Rand, is a conglomerate with pebbles varying in size from that of a hazel-nut to a hen's egg. The association of the gold with the conglomerates is explicable on either of the only two hypotheses which can account for the incoming of the precious metal. If the gold was drifted here, as in a placer, or if by any conceivable means there was some kind of transportal, it seems quite natural that the metal, on account of its density, should be associated with such fragments as are least easily carried off by water, not so much on account of their specific gravity as on account of their dimensions. This description applies to the pebbles, while the fine sands were being carried farther away. If, on the other hand, the gold is simply the result of a chemical precipitation contemporaneous with or later than the rest of the deposit, the percolation of aurifeous solutions must have been much easier amid the wide interstices left by the big pebbles than amid closely compacted sands with few penetrable interstices.†

Agreeing, then, that the auriferous conglomerate is the more usual form of ore, we must proceed to study in it two distinct portions, each

* It may be interesting to recall here for purposes of comparison the characteristic features of the auriferous alluvia of Pliocene age in California and Australia. Taken as a whole, these deposits occur along the ancient *thalwegs* (now below ground) of former rivers, and are localized along the course of these *thalwegs*, as shown by the various shafts and borings. Moreover, the gold there is almost entirely accumulated in the lowest stratum, upon the basement-rock, and chiefly in the hollows and surface-inequalities of that rock. It is only seldom that one or two other beds of auriferous gravel occur almost immediately above this, interstratified with layers of clay. These formations are then very different from those observed in the Witwatersrand. Nevertheless, the mechanical agency of running water has produced an exactly comparable accumulation of the gold in the big-pebbled gravel or "blue gravel" the thickness of which varies from a few inches to 40 or 50 feet. Thus the workings are in gravels and pebble-beds, frequently cemented together by a crystalline siliceous matrix containing in abundance cubical iron pyrites, in a word, a kind of auriferous conglomerate. The gold is associated solely with these pebbles and not with the intervening clays; and the precious metal is the better concentrated according as the preliminary mechanical "sorting" has been the more complete. This is well shown by the clear line of division betwixt the clays and the various gravels (see the writer's *Traité des Gîtes Minéraux et Métallifères* [Earthy Metalliferous Deposits], vol. ii., page 964).

† The richer portions, as we have already observed, occur frequently in certain thin seams with big pebbles (or leaders) next to a practically barren conglomerate. Sometimes these rich bands with big pebbles occur at the base of the reef, and this is the logical consequence of the mechanical sorting which results from sedimentation, and thus it is in the south reef in the Central Rand. But sometimes, too, they occur in the upper portion, as in the main reef leader of the same zone.

of which may have originated from an entirely independent cause. The pebbles are of greatly varying size, and the most important point to note is that they never contain gold, whatever their diameter may be, except at times in small cracks or fissures. In the matrix, on the other hand, gold is concentrated in association with iron pyrites and silica.

The pebbles and the matrix are, as a rule, very closely cemented together. Save at the outcrops, where the action of surface-waters has dissolved the pyrites and crumbled up the rock, they make one mass, and it almost invariably happens on breaking off a piece of the conglomerate that pebbles and matrix break together along one and the same plane: the pebbles being distinguished merely by their elliptical or circular section, sometimes darker, sometimes lighter, than the surrounding matrix.

Let us turn our attention first of all to the pebbles. The pebbles of the auriferous conglomerates of the Main Reef Series are always and invariably made up of quartz or fine-grained quartzite of a dull black hue. In certain big-pebbled reefs, either above or below the main reef, there occur also pebbles, often of large size, of coarser-grained quartzite, analogous to that which encases the deposits. One never meets with any trace of older rock, such as gneiss, granite, granulite, etc. The conclusion to be drawn from this fact is apparently that these pebbles are the result of driftage sufficiently prolonged to have destroyed all the more friable rocks, leaving only the quartz behind, which, in a trituration of this kind, is the last to get ground down. It has already been observed that the frequent presence of flat pebbles, in particular in the south reef, leads to the inference (and this is indeed true of the general aspect of the formation) that the driftage took place, not along a watercourse, but by wave-action on a beach. Sometimes the flat pebbles are massed obliquely to the stratification (New Crœsus mine), as may be noted in certain recent deposits of the same nature.*

The quartzes in the conglomerates are of several kinds, but they have this character in common that they are all hyaline and just slightly glassy (neither opaque nor milky). Some are bluish-white, others smoky-black, the latter have in some mines the reputation, for which there is but little justification, of indicating rich ore. Under the

* Dr. Koch (in Prof. Schmeisser's book, *loc. cit.*, page 46) has observed that these flat pebbles often bear traces of mechanical agency, and the observation is quite true. But it seems quite impossible, after examining them, not only by means of a few sample-pebbles, but as great masses of ore in place, to attribute their flattening merely to some phenomenon of compression.

microscope they are seen to be seamed with lines and filled with inclusions, and they present the character of broken quartz which has undergone dynamical action.

When one looks at a detailed section of the conglomerate, one notes constantly the existence of angular fragments, or of pebbles with blunted angles. These are no doubt the result of breaking up almost *in situ* of some of the larger pebbles. Sometimes, too, angular fragments of quartz appear to dovetail into each other, being separated merely by pyritous venules, just as if here again we were dealing with a big broken pebble (broken perhaps after the formation of the conglomerate) whose *débris* will have remained practically in juxtaposition.

In some cases, too, the passage from the pebble to the encasing matrix is difficult to follow. It is as if the matrix formed one mass homogeneous with the pebble; and indeed there may well have been secondary re-crystallization.

Finally one notes over and over again within these quartz-pebbles, particularly in those of the south reef, internal fractures, cracks showing that subsequent to deposition they were subjected to tremendous pressure and shearing.

The matrix which cements these pebbles together contains very visible iron pyrites, silica, crystallized in place either by means of a chemical precipitation (analogous to that which brought about the direct deposition of crystalline pyrites), or by means of secondary action. The other constituents are white mica and chlorite in fair abundance, including quartz-grains with broken, jagged or rounded outlines, and finally, gold. Under the microscope one observes, among the accessory minerals, some of the most strongly-resisting of the ordinary constituents of crystalline rocks—rutile, zircon, etc.

We may say at once that, as a general rule, gold is not visible in the Transvaal ores. It is only by a very rare exception that a little native gold has crystallized out (as a result of secondary solution) either on a joint-face on which it forms a film or in a quartz-vein in which the crystals are at times fairly large.* But excepting a chance occurrence such as this, one may range through the entire workings on the Rand without seeing a trace of gold.

And yet there is a certain proportion of free gold in the ore. Its presence is ascertained either by microscopic examination, or, more easily

* Some fine samples have been obtained from the Jumpers and Wemmer mines, etc.

still, by a simple assay in the pan. This isolates at once, even in ores from great depths, a yellow streak of native gold, accompanying a streak of pyrites which is also auriferous. Under the microscope, the free gold is seen in excessively thin, transparent yellow-brown flakes, with a violet tinge. When these flakes reach the normal thickness of slides, that is $\frac{1}{100}$ millimetre, the gold becomes opaque, but is still differentiated from the pyrites by its brighter yellow.

Whether free or combined, the gold is in unmistakable relation with the iron pyrites, and this agrees also with the observations noted in most gold-mines all over the world. At the beginning of mining-work in the Transvaal it might have been possible to doubt this. By a well-known phenomenon the surface-ore (that is down to a depth of 50 or 200 feet according to the water-level of the country) had in fact undergone alteration due to the contact of waters charged with oxygen from the air, and the pyrites had been dissolved away, having more or less regular cavities behind. Within these cavities the gold alone had remained free and capable of direct amalgamation, either under the form which it had at first within the now-dissolved pyrites or at times in masses of larger size, having been subjected to solution followed by reprecipitation. Passing below the water-level one meets with the pyritous ore or the "blue," and the proportion of gold capable of direct amalgamation is now much decreased. But this gold, which escapes amalgamation, is found in association with the pyrites, whence it is detached by means of potassium cyanide.*

It does not seem necessary to bolster up, by means of a great array of evidence, a fact so generally admitted as the association of the gold with the pyrites. One of the most cogent proofs of all is that the concentrates, wherein is accumulated all the gold that has escaped amalgamation, are made up of pyrites alone. Moreover, one may note, directly under the microscope, the presence of gold-crystals, recognizable from their more distinctly yellow hue, enclosed in pyrites. But it must, on the other hand, be borne in mind that not all the pyrites in the Transvaal necessarily contains gold. Wherefore the presence of pyrites in abundance and the resulting dark tinge of the ore, although highly probable indicators of its richness in gold, do not allow of an even approximate estimate being formed.

* The question has been often debated as to whether the gold had chemically combined with the associated iron pyrites. The fact, however, that this gold is almost entirely soluble in potassium cyanide, while the pyrites remains unattacked, would appear to tell against such a supposition.

Moreover, in saying in a general way that the gold is associated with pyrites, one does not mean to imply that it is derived from the latter by decomposition, but simply that it was deposited at the same time by a coincident phenomenon.

This unmistakable relationship between the occurrence of gold and that of iron pyrites being granted, our first care evidently should be to study the conditions of occurrence of this pyrites, and thus we are led to make several highly interesting observations.

The first is that the pyrites is often in rolled or more or less broken grains, blunted or rounded at the edges, which can hardly have been deposited exactly in that form. Consequently, between the time when it crystallized out, and the time when it assumed in the ore the position in which we now see it, it must have undergone driftage over a short distance. This observation is of essential importance, for every time we make it we are evidently under the necessity of abandoning what might have seemed a plausible theory, that of the deposition of auriferous pyrites by subsequent impregnation of permeable strata which played the part of a filter or a sponge.

The rolled condition of the pyrites is from the very first quite unmistakable, even to the unaided eye, in a reef situated at the very top of the series, the black reef of Orion, to which attention has already been drawn. In this instance the pyrites-pebbles are as much as 0·10 to 0·20 inch in diameter, and have rather an oolitic appearance. From ooliths they differ, only because in section they show no concretionary structure. So large a diameter in the case of a substance so friable as pyrites would lead one to infer that the driftage of the pyrites cannot have lasted any considerable length of time, since it allowed of the existence of these small pebbles.

Apart from this reef, it will be sufficient in the case of most of the ores belonging to the Main Reef Series merely to examine the pyrites with a magnifying-glass, or with the microscope, in order to see the rounded shape of some of the grains. This arrangement is not unconnected with another circumstance to which attention has already been called, namely, the existence in certain ores (Wemmer mine—fourth and seventh levels: Wolhuter mine—fifth western level: City and Suburban, Champ d'Or, etc.) of pyritous zones, either parallel with or oblique to the bedding, such as are seen in all disturbed sedimentary formations.* These zones

* In the same connexion one finds another example at the New Crœsus mine in the main reef, third western level, where big flat pebbles occur, inclined obliquely to the bedding.

are themselves largely made up of pyrites-grains with blunted angles or rounded edges, and side by side with them occur pyrites-crystals with very fine ramifications penetrating between the quartz-grains and not crystallized *in situ*.

We are then impelled to conclude that driftage must necessarily have had much to do with the deposition of the gold amid these ores.

On the other hand, crystalline pyrites, forming either isolated crystals or secondary groups, at times moulded on the quartz-grains, as in the case which has just been quoted, is also of extremely frequent occurrence in these ores. This may indeed be occasionally attributable to a secondary recrystallization which is well known to be a very usual phenomenon in the case of such substances as silica, iron pyrites, etc.* It may also be traced to far more complex agencies, more especially to chemical precipitation *in situ*, which then excludes entirely the hypothesis of driftage.

Moreover, this pyrites is only stratified in very rare cases; seldom, indeed, is it met with in the form of a band or layer, but it is scattered in every direction amid the mass of conglomerates from top to bottom, in defiance of all the rules observed in alluvial gold deposits.

One of the most frequent modes of occurrence of this pyrites is as a sort of crust around the pebbles, in such wise that in the zone of surface-alteration, where these pebbles are easily loosened from the matrix, one finds occasionally in the hollow left by the pebble an auriferous lining. This would lead to the inference that the surface of the pebbles has had a "precipitating action" upon the pyrites similar to that observed in all pebble-filters through which metallic solutions are passed. These various facts, which will have to be taken into account, coupled with the fundamental observation that the pebbles never contain gold, point to the conclusion that this formation is the result of something else than mere transportal and erosion of material derived from auriferous quartz-veins —a conclusion which has been very generally admitted, even in the case of placers.

In order to complete what has been said concerning the ores it will suffice to add that developments of secondary mica or talc are fairly often traced along the fissures, while microscopic white mica is scattered about in the rock. Moreover, veins of milky-white quartz, 2 to 4 inches thick,

* In the auriferous placers of California one finds at the base pyrites crystallized *in situ* by secondary action. We must get accustomed to the idea that metalliferous ores, such as iron pyrites, and even gold itself, are far easier to set moving again by solution than was at one time supposed. And more especially as to the gold: even if the geodic concentrations in venules at the outcrops of the auriferous quartzes of Australia did not superabundantly prove our point, we should find direct proof of it in the ease with which its solution is nowadays effected in extraordinarily weak solutions of potassium cyanide. This may also be accomplished with chlorides, nitrates, etc.

are sometimes found, charged with metallic sulphides or even crystalline gold, although they are considered barren as a general rule, from the practical man's point of view.

Apart from the gold and iron pyrites which make up some 30 per cent. of its mass the Witwatersrand ore is remarkably poor in other metals, and this very sterility contributes perhaps to the facility with which it lends itself to the potassium cyanide process. In most of the mines that he visited the writer was told that the presence of metals had never been detected, excepting a few traces of silver or copper. The last-named metal was occasionally visible on the zinc which precipitates the gold from the cyanide solution. This general non-occurrence of metals was brought to the writer's personal notice in the case of concentrates coming from the Wemmer mine, and assaying 9 grammes of gold to the metric ton. They held no trace of copper, zinc, or lead, and the chemical analyses made at the Paris School of Mines revealed the presence of only 4 per cent. of arsenic. It is only in the veins of secondary quartz mentioned above that metals are sometimes met with. Thus the writer found galena and blende at the Buffelsdoorn mine, chalcopyrite at the Robinson mine, and crystals of pyrites and blende at the Crœsus (third eastern level, on the south reef). Moreover, Prof. Schmeisser has noted the presence of a little blende on the Alexandra Estate and Rietfontein properties, and traces of antimony in the west of the Rand. The writer himself, as before stated, ascertained the presence of foreign metals in the ore of the Orion mine, which is somewhat refractory to cyanization.

It now remains to say a word concerning a question the practical and theoretical importance of which is evident: that is, the modification in depth, not of the tenour of gold (which will be dealt with farther on), but of the structure of the conglomerate which bears an intimate relationship to that tenour on any one of the hypotheses put forward—whether there may have been contemporaneous precipitation of the gold and pebbles, or simply later impregnation. The writer asked himself, and sought to answer the query by personal observation in all the mines that he visited, whether the deeper down one went there was not some change in the structure, dimensions, and more or less rounded condition of the pebbles, changes which would have been the indices of corresponding modifications of the conditions which attended the formation of the auriferous deposit.

From the point of view of the interpretation of geological phenomena there is so great a difficulty in conceiving how conglomeratic formations

or pebble-beds, supposed to be of littoral origin, can have extended over a breadth of many miles, that the exact verification of the ascertained facts is of prime importance, and one must make very sure that one is not the victim of an illusion in regard to them.

Nevertheless the general study of the country, in proving to us the existence of a great synclinal, on whose two limbs occur practically identical, quartzites and conglomerates, gives an air of great probability to the correlation in depth of these two zones. They dip in opposite directions, and yet are probably joined up by similar beds which prolong them on both sides.

Moreover, another theoretical observation may be made, that is, that the present outcrop, representing the intersection by an horizontal plane of a folded stratum, cuts this along a line which is most certainly very far from being the ancient shore; in such wise, that successive points taken along the outcrop are, in relation to this shore, as differently conditioned as two points taken at different levels on the dip of a bed. And more especially in the portions which have been tilted up very steeply, the erosive agencies that have carved out the present surface-features of the country must have swept away a far larger proportion of auriferous rocks than is the case with the beds that lie nearly horizontal. If to this remark we add that there is absolutely no evidence as to the whereabouts or the supposed trend of the hypothetical shore-line, since the general direction as we now see it is the result of folding of much more recent date than the deposition of the beds, it will be admitted that there is no *a priori* ground for assuming along the dip of the reefs variations different in kind from those which have been observed along their strike. Zones with big pebbles are succeeded by zones with small pebbles, angular pebble-bands alternate with rounded pebble-bands, rich seams with poor, following no recognizable law or order.

Such is the conclusion which experience of the workings now in progress appears entirely to confirm. Nowhere has the present writer observed concurrently with increase in depth from the surface any progressive diminution in the size of the pebbles, any change in the proportion of angular fragments to rounded pebbles, such as should have been noted if the influence of remoteness from the point of origin had intervened as a factor. So far as size is concerned, it will suffice to mention at the eighth western level of the Wemmer mine, in the south reef, and at the seventh western level in the main reef leader the presence of very big pebbles about 3 inches in diameter, the like of which had not been seen at the higher levels.

D.—Gold Tenour of the Ore. Its Variations according to the Strike and Dip of the Beds (Deep Levels).

The gold tenour of the Transvaal ores suggests some general remarks by which it will be as well to begin.

When a newcomer fresh from Europe starts his inspection of the Transvaal mines, in the slightly mistrustful frame of mind—more or less mistrustful according to individual circumstances—which appears to be very general among such visitors, he is unpleasantly surprised by the fact (to which he accustoms himself, however, in time) that it is quite impossible to distinguish with certainty by the eye alone an ore assaying 3 kilogrammes from one assaying 10 grammes of gold per metric ton. He learns, moreover, that trial assays, however careful, unless they are continually repeated from the same bed, can only give a remotely approximate, nay sometimes an erroneous idea, of its industrial value. Wherefore the most conscientious of engineers, unless he has both the time and the right to remain permanently at a particular mine, is unable to form a perfectly independent and personal opinion as to the value of the ores worked there. There is only one really practical method of ascertaining the facts—that is, to examine the results of crushings on a large scale, sufficiently prolonged and carried out under the same conditions as those that obtain in actual practice. Thus there must be no choosing for the experiment of the probably richest portions, as a mines manager may so easily do, having the laboratory assays to guide him. If our newcomer proceeds in this manner, his possibly exaggerated scepticism must give place for a time to unquestioning faith.

The impossibility of distinguishing, even remotely, by their appearance, the respective values of the Witwatersrand ores is chiefly due to the fact already referred to, namely, the gold is nowhere visible. The pyrites with which it is generally associated is a very insufficient indicator of the presence of the precious metal; for although there is very little gold without pyrites there is, on the other hand, plenty of pyrites without gold. It frequently happens that the most experienced men in the country make a mistake as to what they consider a promising ore, the supposed favourable characteristics being a dark pyritous matrix, enclosing sufficiently large and wide-spaced but not too scattered pebbles.

As to the small value of an isolated assay this is due to the very natural irregularity of the deposits, which we in Europe wrongly imagine to be mineralogically and geologically constant in character. This preconceived opinion is based on the fairly regular and continuous industrial

results obtained from the ores, these results being particularly conspicuous when one compares them with those yielded by other gold-veins known and worked long before those of the Transvaal.* But in any reef on the Witwatersrand, as is shown at once by any plan of trial-workings and assays, one will find at a few inches distance, without apparent reason for the change, variations from 2 to 100 grammes of gold per metric ton. So that, however carefully an assay may have been arranged, according as the ore has been taken from one or other of these points, it will yield results so divergent as to be contradictory. And it may as well be said now that we have here ample grounds for attaching only slight importance to certain analyses of ores made in the exploration-workings of new mines. The results yielded by these analyses, often announced with so much pomp and circumstance, prove very little either way, unless one obtains a very long series of analyses.

Now that this question of local variations in the gold tenour has been touched upon—a point which even the most impartial mining reports on the Transvaal unfortunately refrain from mentioning—it may be proper to explain how these deposits have gained an undeserved but universal reputation for extreme regularity. It is true that this does in some measure correspond to the real facts of the case, but it has in part been obtained by what may be termed fictitious methods. These methods are, doubtless, perfectly defensible, on condition that one is made aware of them, and that one is thus prevented from interpreting wrongly the consequences which flow from them.

One curious—all but paradoxical—phenomenon of these auriferous conglomerates in the Transvaal is, that although the gold tenour varies constantly from one point to the next, nevertheless, if a sufficient length of reef be taken into consideration, an average gold-tenour will be struck which remains comparatively steady for each mine or district of a mine.

This steadiness, only approximative be it said, results in part from the sedimentary character of the deposits, and the illusion is heightened by the very restricted area—usually overlooked at the first glance—of the oldest-known properties. For example, the Pioneer is 328 feet long, following the outcrop; the Worcester or the Bonanza, 820 feet; the Wemmer, less than 1,640 feet; the City and Suburban, 2,296 feet; the Crown Reef, 2,952 feet; and the Robinson, 3,608 feet. It is quite evident that the smaller the extent of the workings the greater is the chance that they will remain all the time in the same geological zone in which auriferous metallization has taken place under comparable con-

* See, for example, the assay-diagrams in Plate XXV.

ditions, and thus the treatment of ores from a given mine may long yield practically identical results. But even this constancy must not be exaggerated when confined to these restricted limits; for, despite everything, it happens often enough that considerable variations are noted for better or for worse when going from east to west in a claim, or from one level to the next. As may be readily conceived, variations for the better are those which are most frequently brought to the knowledge of the public.

Thus, at the Witwatersrand mine, the assays obtained from the first level had induced a celebrated American engineer to consider the property as worthless. In the western district more especially, over a large area, assays of less than 10 grammes per metric ton were the rule; but in the corresponding portions of the second level assays of 70 to 80 grammes per metric ton were obtained, and no one can predict whether the third and fourth levels will most nearly resemble the first or the second.

Similarly, at the Bonanza mine, on the south reef at the third level (which has in consequence been actively worked at) the average yield of the assays was 50 grammes per metric ton. The first and second levels, which have been very little worked at, had shown rather poor results.

At the Geldenhuis Estate mine, this order of things has been reversed. Up to March, 1892, in the belt of decomposed rock, an average yield of 30 grammes per metric ton had been obtained. Then the gold tenour changed—partly because the workings had now reached the pyritous ore, partly because the number of stamps having been increased the poorer ores, hitherto neglected, were now crushed as well as the richer ores. Thus it was that, in June, 1893, the average tenour was 24 grammes per metric ton, and up to the end of 1894, without any change in the workings, it gradually fell to 12 grammes. At the present time the tenour has risen again to 18 grammes, despite the putting down of more extensive plant which crushes still poorer ore. It is true that, in reckoning this gold tenour, the yield by the cyanide treatment, only recently introduced at the Geldenhuis Estate mine, is taken into account.

We might easily multiply examples of this kind. In every mine are districts more or less rich, more or less poor, succeeding each other without any apparent order; and it would, of course, be futile to term "constant" an average tenour which varies so enormously. Nevertheless it is perfectly true that the gold-mines of the Witwatersrand are favourably situated in comparison with the vein-gold mines previously known, where the variations are far more brusque and pronounced, and where once a certain depth has been reached impoverishment of the ore regularly sets in. But nearly all the mines in the Transvaal have adopted a very wise

plan of action—which it will be of interest to study—in order to remedy these variations in tenour, avoid sudden checks in the yield, and make the dividends regular, to the great advantage of the shareholders.

The system consists, in the first place, in carrying forewinning-work very much in advance of actual winning, so as to be able to establish continually working-places, as may be desired, at a large number of different points, without interfering with the good conduct of the working of the mine.*

On the other hand, each mine possesses what we may call a trial-and-assay plan; that is, a plan of the workings whereon are marked day by day—(1) the results of analyses† of samples of ore taken at distances 30 feet apart; and (2) the corresponding thickness of the ore at each sampling-point. They give in this way a sort of picture of the mine, with all the details of the gold-bearing strata.

Besides these assay-plans, whence one might, perhaps, attempt to draw a few theoretical conclusions, all engineers who know their work well are continually making assays—perhaps rather rough and ready, and yet extremely rapid —by means of the American pan. With a little practice these give a quite sufficiently near approximation to actual results. By means of these various methods, therefore, the engineers are in a position to know at once which are the rich and which are the poor districts of a particular mine; and thus by distributing carefully their workpeople, the company are enabled to regulate the output in accordance with the wishes of the directors and shareholders. Any accidental decrease in the gold tenour—which is, of course, to be foreseen in masses so heterogeneous as a mining deposit—always necessitates very lengthy explanations for the benefit of the directors and shareholders.‡ In case of need, if that method

* In the latter months of 1895, scarcity of labour induced a decrease in the work of forewinning, as it was deemed inadvisable to diminish the apparent profits on the general working of the mines. This partial suspension of forewinning may be the indirect cause, some day or other, of more than one unpleasant surprise.

† The analyses or assays always yield better results than those obtained in practice; but the average obtained allows of the industrial output being estimated to some extent. The existence of these very detailed plans, manifestly quite straightforward (with an occasional exception as to the manner in which the assay-samples, which are the basis of these plans, are taken), the ungrudging way in which they are communicated to visitors, together with the laboratory books by which they can be checked, are among the circumstances which most contribute to inspire confidence in the general character of the technical and industrial management of the mines.

‡ The great publicity to which the Transvaal mines are subjected, the speculations to which they give rise, and even the low initial price of the shares—the very price of which encourages their dispersion in the hands of a multitude of uninformed persons, impose on the managers of the mines certain restrictions and conditions, among which the obligation to regulate the gold tenour in a manner which the nature of the deposits hardly allows, is perhaps the least objectionable.

of procedure does not suffice, there are always held in reserve some heaps of particularly rich ore, of which some portion is crushed towards the end of the month in order to raise the general total; or in scraping the amalgamation-plates a little gold may be left on the surface in a prosperous month, and then taken off and utilized when times are not so good.

As was said above, we can hardly pretend to criticize adversely these little artifices, the object of which is to avoid giving any cause for overelation or for excessive despondency in the matter of an industry so exposed to public view as gold-mining, the results of which are frequently set down in print, so eagerly and often so unintelligently commented upon. To these artifices there are, however, as may be readily conceived, two great objections.

On the one hand, if in a mine of considerable extent, one may nearly always so arrange the working-places as to approximately realize this unnatural constancy of gold tenour,* this is very far from being often the case in the smaller mines. In such circumstances we have known managers, tormented with the idea that their average assay-figures would go down some points in the monthly publications, hew down unreflectingly whatever rich stuff they had in the mine. So that when the poorer belt was unduly prolonged, they were overtaken one day by a disaster or collapse, which they would have avoided had they owned at once that there was for a time some impoverishment of ore.

On the other hand, it is not difficult to guess how certain unscrupulous persons would profit by the method, which consists in working sometimes the richer and sometimes the poorer districts of the mine—according as it is proposed to make the price of the shares go up or down. But it is only fair to add that such artifices appear to be of less frequent use on the Witwatersrand than in many other gold-bearing countries. And, even when they are brought into requisition, the great proximity of the various properties which dovetail into one another, the continual changes going on among the engineers (who very often leave one mine to take up the management of another), the frequent intercourse with the staff, bring these methods so quickly to the notice of the public that their injurious effect is destroyed.

It is, perhaps, precisely because they felt the need of inspiring confidence that the mining companies of the Transvaal have set themselves to do what is done in no other mining district in the world. Indeed,

* So far, the progressive improvements in the treatment of the ores, allowing of the extraction of a greater and greater proportion of precious metal from ores of similar grade, have much facilitated this task.

the exigencies of industrial competition would not permit of its being done for any other substance than gold. In a word, they have opened wide to all comers the doors of their mines, workshops, laboratories, etc.; they show everything, from their assay-plans to their tables of prime cost, and they publish all the results of the workings in carefully detailed reports at least once a year, and in some cases once a month. Under these circumstances, saving some restrictions, the chief of which have been already mentioned, and saving the case of a few mines where there does not appear to be so burning a desire to throw much light on the actual state of things, one is quite naturally impelled to have great faith in the general character of the mining industry on the Rand.*

As to the trust which one may put in the semi-official publications† dealing with the gold-mining industry, only one remark need be made, and that concerns the number of tons crushed from which the gold tenour as published is directly calculated. This number, which is given with a great show of precision, is in reality only the expression of an approximative estimate based on the number of waggon-loads. But these are never weighed, nor is it practicable to do so; and so a manager, desirous of earning the reputation of working a mine economically, may be induced to exaggerate the weight of ore contained in his waggons (*e.g.*, by filling them incompletely, but continuing to reckon them as weighing the same as if they were full), and his actual expenditure being thus spread over a greater number of tons, the cost per ton of ore hewn and treated looks very low. The manager may, too, by an inverse arrangement, force up the apparent tenour to the detriment of the prime cost. It is, perhaps, owing to this that the figures of prime cost vary from one figure to double the amount in analogous mines, and because of this, too, that, apart from a certain amount of waste which is a very considerable factor in rich companies, this prime cost is often the higher the richer the ore is.

Turning now from these questions of a general nature, it is proposed by means of statistics to give some idea of the gold tenour of the ores in the various mines of the Rand.

* It need hardly be repeated here that the gold-mining industry is alone alluded to, and no reference is intended to the financial operations which may be grafted on to it, either in the Transvaal or in Europe.

† The Johannesburg Chamber of Mines, which is responsible for most of these publications, has no official character and no right to force any company to communicate to it the results obtained in working. But, in practice, most of the mining companies are affiliated to the Chamber.

This tenour, as already observed, may be calculated in two ways, either from the laboratory assays or from the actual industrial yield ; this, as a rule, varies between 50 and 85 per cent. of the figure calculated from the average of the assays. The industrial yield alone comprises several portions; the gold obtained on the amalgamation-tables, then that extracted from the tailings by cyanization, and in a few mines that obtained from the concentrates by chlorination; finally, at this very time an attempt is being made to extract a portion of the gold contained in the slimes, of which all the mines have vast reserve stocks.

The subjoined table shows the industrial yield of the various mines in 1895.* Moreover, the writer has endeavoured to recopy these gold-tenours on to the diagram (Fig. 9, Plate XXIII.), so as to show up, however, roughly, the alternating rich and poor belts on the Rand.

As regards these yields, one observation of some importance must be made, namely, that they cannot be compared one with the other, except in a rather remote fashion. For, if a certain mine works only a rich bed, leaving aside until a future occasion the poorer beds (as happens, for instance, when the mining company have only a very small battery at their disposal) the average apparent gold tenour of the ores will come out higher than that of a neighbouring mine where they will have begun working on a large scale of some comparatively poor reef, such as the main reef in the Robinson, Jubilee, and other mines, the ore extracted from this poor band being mixed with that got from the rich bands. In a general way, it is said on the Rand—a saying which appears rather startling at first sight and the meaning of it must not be taken too literally—it is said that to increase the number of stamps in a mine, results in an increase of the quantity of gold contained in it, while lowering the grade of the ores. So too, if the ore be very carefully picked and sorted, there will be a higher gold-tenour per ton crushed, but this will be spread over a lesser number of tons.

This remark applies with equal force to the comparisons which may be instituted between the gold-tenours of the ores from the same mine at different times. It is somewhat surprising that very distinguished observers, doubtless being unprovided with sufficient data, took no account of this when they arrived at the conclusion (seeing the diminution of industrial yield as time went on) that the mines of the Transvaal became poorer and poorer in depth. This decrease in the yield is the

* All the estimates made in the Transvaal are reckoned in American short tons of 2,000 lbs., or 907 kilogrammes, that is, about $\frac{1}{10}$ less than the metric ton. This point is often lost sight of. The results given in the present paper have all been converted into metric tons of 1,000 kilogrammes.

TABLE SHOWING THE AVERAGE RESULTS DURING THE SIX MONTHS (APRIL-SEPTEMBER, 1895), ACCORDING TO THE STATISTICS PUBLISHED BY THE CHAMBER OF MINES.*

Names of Companies.	Gold Tenour in Crushing per Metric Ton.	Gold Tenour in Tailings per Metric Ton.	Total Gold Tenour per Ton Crushed.
	Grammes.	Grammes.	Grammes.
Champ d'Or	17·22	8·61	22·90
City and Suburban	12·10	6·95	16·69
Crown Reef	14·31	8·03	19·61
Durban Roodeport	16·44	10·10	23·10
Ferreira	36·54	13·96	45·75
Geldenhuis Estate	12·54	7·47	17·47
Geldenhuis Main Reef	14·35	11·43	21·90
George and May	9·55	10·12	16·23
George Goch	10·50	10·27	17·27
Ginsberg	17·07	8·91	22·94
Glencairn	14·25	10·75	21·34
Henry Nourse	22·21	13·22	30·93
Johannesburg Pioneer	23·69	14·72	33·40
Jubilee	16·53	8·38	22·05
Jumpers	15·54	6·21	19·63
Lancaster	9·60	8·09	14·93
Langlaagte Block B.	9·37	3·86	11·91
Langlaagte Estate	13·01	5·11	16·38
Langlaagte Royal	6·32	5·39	9·87
Langlaagte United	7·81	9·03	13·78
May Consolidated	11·91	7·76	17·03
Metropolitan	9·97	6·57	14·31
Meyer and Charlton	18·54	7·52	22·54
New Chimes	16·47	5·23	19·91
New Crœsus	7·03	3·64	9·43
New Heriot	16·53	15·16	26·53
New Kleinfontein	11·81	5·31	15·31
New Primrose	11·32	7·80	16·47
New Rietfontein	15·67	7·25	20·44
Nigel	26·65	27·62	44·87
Orion	19·54	37·65	44·47
Paarl Central	13·47	9·50	19·73
Porges Randfontein	17·33	4·46	20·27
Princess Estate	16·53	7·76	21·65
Robinson	32·58	8·83	38·40
Salisbury	16·70	9·12	22·71
Simmer and Jack	16·38	7·07	21·12
Stanhope	12·26	10·36	19·20
United Main Reef	19·21	8·95	25·11
Van Ryn	15·82	6·16	19·88
Vogelstruisfontein	7·00	—	—
Wemmer	24·38	10·93	31·58
Wolhuter	15·51	9·02	21·46
Worcester	28·62	—	28·62

* In order to obtain these figures, the averages shown by the official tables have been converted into metric tons and grammes. For determining the total gold-tenour, account has been taken of the generally admitted proportion of the tailings treated in relation to the number of tons of ore crushed, a proportion which is about 2 : 3. For this reason, the total gold tenour is not the sum obtained by adding up the first two columns. It will be observed that these results are not absolutely comparable, the gold produced by the various mines not being equally fine. Thus for the gold obtained by amalgamation in September, 1895, the above-mentioned tables show that the ounce of gold was worth £3 16s. 1d. at the Champ d'Or mine, £3 13s. 6d. at the Ferreira, £3 18s. 9d. at the Nigel, and £3 15s. 1d. at the Robinson mine Similarly, gold obtained from the tailings by cyanization was worth, in the same month, £3 9s. 3d. per ounce at the Crown Reef, £3 2s. 8d. at the Jubilee, and £3 9s. 10d. at the Robinson mine. Nevertheless, these differences from one mine to the next are of the same order as those which occur in one and the same mine from month to month, and therefore the appended results may be considered sufficiently approximate

sole result of the simultaneous continuous decrease in working expenses and increase in the dimensions of the batteries, so that those responsible have been induced to extract poorer and poorer ores up till now left aside. This is, of course, translated into figures by a diminution in average tenour, but also by a definite increase in gold-production.

The writer has made some attempts to solve this question of possible variations of the gold-tenour corresponding with the depth from the surface, as it is a question of signal importance for the industrial future of the Rand. But there always crops up that very difficulty that the yields obtained in practice, being the result of a mixture of ores from all levels, give no indication that could furnish a workable basis to start from. In the absence of more satisfactory data, the writer has devoted some time to the study of the assay-plans, rendering these, where necessary, into graphic diagrams so as to make them more effective. And it appears possible to conclude that the variations along the dip are of the same order as the variations along the strike, that is, rich and poor zones will be found distributed, anyhow, without reference to a general law. No indication is given such as to lead one to imagine a progressive impoverishment of the beds (at least within those limits to which mining work is restricted, in consideration of the enormous difficulties of mining at great depths.)*

The apparent variations corresponding to a theoretical law, which it had been thought possible to deduce from observations confined to too limited a field, disappear so soon as the field of study is extended. This also applies to most of the so-called "rules" by which some persons have made a pretence of guiding themselves, in order to predict the existence of rich zones in either direction.

Among these rules one of the most widely known, and one which nearest approaches the truth, is that which admits of a certain relationship between the gold-tenour and the thickness of the reef, the reef being all the richer per ton of ore the thinner it is. Some have even gone so far as to say that in a broad reef the total quantity of gold was less than in the narrow portions of the same bed. If this last statement were true (and the writer's personal observations do not bear it out) we should, doubtless, be compelled to conclude that, in the broader portions, a good many barren sandstone-intercalations are hewn down and subsequently cast aside in the sorting, in process of which a little gold must get lost.

Some of the managers on the Rand believe, on the other hand, that below the zone of surface-oxidation there exists an especially rich mass,

* On pages 414 to 416 some figures have been given regarding this point.

as if a little of the gold from the oxidized zone had been brought downward in solution and had crystallized out there. But this hypothesis does not appear to be borne out by the facts.

Again, one may ask whether the richness in gold would bear any relation to the dip of the beds, to the presence of dykes of eruptive rock, or to the aspect of the faults?

In some mines, such as the Simmer and Jack, it does indeed seem that the beds which are very much tilted up are richer than the flat portions, and a glance at Figs. 8 and 9 (Plate XXIII.) seems also to show a vague correspondence between the maxima of the tenour-curve and the presence of vertical strata. This would lead one to suppose that the dip played some part at the time of the auriferous formation, or, in other words, it will have been already sketched out in some way. But the exceptions to this rule are singularly numerous: it will suffice to mention the rich and very flat reefs of the Nigel mine, of some districts of the Modderfontein, of Durban Roodepoort, etc.

The presence of dykes* has also been considered a favourable indication, generalizing merely from the very hasty observation that in the rich district of Robinson, Ferreira, etc., these dykes are numerous. In reality, when one examines any assay-plan upon which the dykes are marked, one never notes any enrichment along them, or in their neighbourhood. Nor must it be forgotten that the dykes, so numerous in certain mines of the Witwatersrand, cut through and throw back, for the most part, the gold-bearing beds, and were consequently extruded after the deposition of the latter. If traces of gold have been exceptionally met with there (Wemmer, Rietfontein, etc.), it may well be gold carried off from the strata passed through. As to the iron pyrites, it occurs frequently there in the crystalline state; but this occurrence is quite ordinary in basic rocks of the same family.

Nevertheless, there is no absolute impossibility that certain older dykes exist in the Witwatersrand which have played a part that has yet to be determined. If we make this reservation, it is not only because of the theoretical conception which induces one to attach in a general way the occurrence of metalliferous deposits to that of eruptive rocks, but because in a particular case, that of the amygdaloidal porphyrites of the Klipriversberg and the black reef, this relationship appears really to hold good.

* The dykes consist, in the main, of ophitic diabase, porphyrite, etc., fairly analogous to the rocks which are associated with the great iron and copper pyrites deposits in the province of Huelva in Spain. But at Johannesburg the name "dyke" is also given to any material filling up a fault, such as breccias, laminated and schistose quartzites, etc.

As to the influence sometimes attributed to faults, it is of another kind. By bringing into juxtaposition two portions of reef originally far apart, and by suppressing intermediate portions, the fault may cause the workings to pass suddenly from a rich zone into a poor one, and *vice versa*. Hence the notion that rich zones follow the general direction of a fault.

Moreover, we may note in this connexion that, up till quite recently, faults in the Witwatersrand area were looked upon with mingled feelings of terror and awe, which can only be explained by the great technical ignorance of improvised miners, suddenly called away from the office desk or the shop counter. It is perfectly astounding to note how an insignificant throw of a few feet has been looked upon, according to the optimistic or pessimistic temperament of the observers, either as a cataclysm wherein the auriferous bed might disappear for ever, or, on the contrary, as a sign that some extraordinarily rich beds would be met with farther on.

E.—Origin and Mode of Formation of the Witwatersrand Auriferous Deposits.

The problem of the origin of the gold-bearing formations in the Witwatersrand is an extremely difficult one, and the writer believes that it will so appear to anyone who approaches it without any preconceived notions, embraces it as a whole, and seeks to reconcile the various recorded observations of detailed facts, instead of erecting a flimsy superstructure of theory, based upon a few isolated facts hurriedly generalized. The writer has no hesitation in confessing that, during his sojourn at Johannesburg, and even after his return to Europe, on examining his samples of ore under the microscope, he changed his mind over and over again. New facts kept coming to light, for which it was necessary to find some explanation, and it was only after abandoning all other hypotheses, under the stress of what appeared to him irrefutable objections, that the author arrived at the conception which will be propounded farther on. Meanwhile no attempt will be made to mask what are still the weak points of the theory.

Among the principal observed facts described in the preceding pages, the most important concerning the origin of the gold are the following:—*

(1) The gold ore is a quartzitic conglomerate, or (but seldom) a quartzitic sandstone, whose rolled constituents, pebbles and sand-grains,

* The black reef is here expressly left out of account, as it appears to form an exceptional case.

are almost exclusively made up of quartz, or secondarily of quartzite, and whose cementing-material is a pyritous and auriferous silica. The quartz-pebbles, sometimes well rounded, sometimes simply rounded off at the edges, often flattened, are of two varieties—bluish-white and smoky black. The last mentioned are considered in some mines as a good indicator, although the evidence in support of this is not absolutely unimpeachable.

(2) The beds containing gold in varying proportions, workable or unworkable, are spread through a thickness of several thousand feet of sandstones and conglomerates, with a few intercalated shales at the base, and not a single band of limestone. The limestones first begin to appear above the most recent auriferous bed known, the black reef, just as if at that period a total change had taken place in the conditions of deposition. These various beds of auriferous conglomerate show continual local changes in thickness and in distance from one to the other. Sometimes they are drawn out, or they bifurcate to enclose a mass of sandstone, and then come together again farther on. Nevertheless, in most cases, a bed of conglomerate or sandstone which seems to make a very sudden appearance is only the enlargement of a bed hitherto marked by a mere trace of sand or line of scattered pebbles, and from one end to the other of the auriferous belt the section is fairly constant. The richness of gold seems on the whole, so far as one may form an opinion from observations which are still very incomplete, localized everywhere in the same groups of beds.

(3) The mechanical phenomena which were posterior to the formation of the conglomerates were both numerous in kind and unmistakable in their results. In the first place, one will have noted in this connexion the dip of the strata, and their arrangement in an east-and-west synclinal, the results of a later folding, as the present pitch of the reefs is absolutely irreconcilable with the conditions under which they were deposited. We have noted moreover the presence of real clayey salbands along surfaces of slip and crush; the existence of a network of fissures wherein quartz with iron pyrites, chalcopyrite, galena, blende, and sometimes native gold, have crystallized by segregation; the faults, mostly striking north-east and south-west; and lastly the dykes of eruptive rock, whereof the chief one (that of the Klipriversberg) may possibly have had something to do with the formation of the black reef.

(4) The gold in the ores is often in the free state, but so finely divided as to be invisible to the naked eye. It is invariably associated with pyrites, although never, as it would seem, combined with the latter.

Under the microscope it may be often seen in crystals included in the pyrites itself. This pyrites, which often forms as much as 5 per cent. in weight of the rock, is, as a general rule, remarkably pure, and contains only exceptionally traces of copper, lead, and zinc.

(5) The gold and the pyrites occur solely in the cementing-material of the quartzose pebbles. The pebbles themselves, whatever may be their size, never contain either mineral, except very rarely in fissures. The mode of occurrence is so general and so constant that it is difficult to conceive one and the same cause as originating the quartzite-pebbles and the auriferous pyrites. It is evident that the last-named is the result of the erosion of veins of metalliferous quartz.

(6) The auriferous pyrites generally enwraps the quartz-pebbles, upon the surface of which it seems to have been precipitated, or else it forms irregular venules in the siliceous matrix of the conglomerate. In some cases it forms bands of venules, either parallel to the general stratification, or at an angle with it corresponding to a false bedding of the sediments. On examining the pyrites with a magnifying-glass or under the microscope, it is seen to be sometimes rolled, particularly when occurring in parallel venules. At other times it is well crystallized, and must have been deposited *in situ* by chemical precipitation (exactly analogous to that which in other countries has formed metalliferous veins), simultaneously with a portion of the associated quartz.

(7) There is an universally admitted relationship between the size of the pebbles and the richness in gold of a limited portion of a given group of beds. The fine sandstones are only very exceptionally gold-bearing, and then merely along particular lines of scattered pebbles, not very plainly visible. In the conglomerates themselves the layers with big pebbles are considered to be especially rich, particularly those which are at the base of a bed. The ores generally regarded as promising are those with rather large pebbles, widely, but not too widely, scattered, with a dark cementing-material, the hue of which is to be partly ascribed to the particular variety of quartz and partly to the abundance of pyrites.

(8) In a bed of conglomerate, the gold is by no means concentrated all at the base, as it is in auriferous placers. Either it is spread uniformly through the whole mass, or if localized in one stratum this rich stratum may be either in the upper or in the lower part of the bed, though it is true that the second case is the most frequent.

(9) In one and the same bed the tenour in gold per ton appears (although the rule is not of invariable application) to be higher accordingly as the bed is thinner, just as if there had been only a particular

quantity of gold available for the permeation of the entire thickness of the bed.

(10) A certain number of reefs, many of them very rich, occur at the junction with shales, intercalated between these and the quartzites (East Rand, Van Ryn, Modderfontein, Nigel, and Midas mines, etc.).

We will now try and see whether there is one interpretation into which all these facts will fit.

It has been already pointed out that if one considers first of all the formation of the quartzites and conglomerates, independently of the occurrence of gold in them, one seems to be dealing with a vast area of deposits, in nowise restricted to the small lake-basin pictured by some theorists. Further, that these deposits are possibly of marine origin,* and were no doubt nearly horizontal at their inception, whereas their present dip and arrangement are due to the later folding which has formed the great north-east and south-west synclinal.

As to the presence of gold, which is in no respect the necessary correlative of the development of the conglomerates (on the contrary, it constitutes in all probability a purely local phenomenon) all the hypotheses whereby one may attempt to account for it are perforce reduced to three, namely, that the gold was formed either before, at the same time as, or else after the conglomerate.

On the first hypothesis, adopted by the present writer when he wrote his former paper on the Transvaal, and supported also by Messrs. Schmeisser and Goldmann, gold and pebbles alike are the products of erosion or denudation of ancient quartz-veins. The *débris* of these are supposed to have been drifted along and subjected to other mechanical agencies, so that we should be dealing here with a true placer dating from the Primary period. As it is necessary to explain the highly important and constantly observed fact that both the gold and the pyrites are to be found only in the cementing-material, but

* The hypothesis of a marine formation is tentatively put forward, for the reason that the Witwatersrand conglomerates occupy an intermediate stratigraphical position between two beds containing marine fossils, the Bokkeveld Beds and the Carboniferous limestones. Moreover, the vast extent of the formation, or of analogous formations, whereof the traces have been recorded at opposite ends of Southern Africa, the comparative regularity of the beds, and the frequent occurrence of flattened pebbles, are more the features of a marine than of a lacustrine deposit. Perhaps the notion of widespread fluviatile formations, of torrential deltas distributed over an alluvial plain, such as that of Lombardy, might occur to one. In any case, however, it appears to be a well-ascertained fact that the conglomerates extended north and south of the Witwatersrand, far beyond their present limits, and that their disappearance is simply the effect of later erosion.

never in the pebbles, one may go so far as to add (in order to justify the hypothesis) that the auriferous portions of the quartz being the most friable were the most completely destroyed, and that the fragments split up along the venules of auriferous pyrites as these formed lines of least resistance, whereas, on the other hand, the barren nuclei withstood such erosion. Another explanation would be that the pebbles were brought from one direction into the basin where sedimentation was going on, while the fine sand of the cementing-material, the gold, and the pyrites were brought into it from another direction.

Nevertheless, these explanations appear to the writer utterly inadequate, and he has mentioned them here simply in order to put on record without bias the arguments on both sides of the question. Their inadequacy is manifest, in view of so widespread a phenomenon as the barrenness of the pebbles. Nor do they help one to understand how so large a portion of the pyrites has evidently crystallized *in situ*, while the rolled pyrites bears the merest trace of a short and far from violent driftage.

On the second hypothesis, that of the contemporaneous formation of the gold and the sediments, which the writer considers on the whole to be the most probable, one may picture a beach whereon fragments of quartz (whence originating is a matter of little consequence) were ground down and rolled by the waves, and here lay gold and iron sulphide brought perhaps by some agency connected with vein-formation; these substances would also be in solution in the water.* They then were precipitated chemically, as were the cupriferous sulphides of Mansfeld or the plumbiferous nodules of the Commern and Mechernich sandstones in Rhenish Prussia, or again the copper ores associated with the conglomerates of El Boleo. Rolled *in situ* by the waves, they would finally have been deposited more or less pellmell with the pebbles.† In order to account for the characteristic circumstance that the gold is almost entirely restricted

* It is plainly no easy matter to picture exactly the course of events. If water is to deposit substances dissolved in it, it must have reached a high stage of concentration, and be of very shallow depth. If we imagine it as a lagoon, this becomes incompatible with the existence of such waves and currents as are capable of rolling heavy masses of pebbles.

† The fact that pebbles of pyrites, generally very friable, have been able to resist the effects of denudation conduces to the belief that they were rolled practically *in situ*, and have not been drifted from a distance, as one would be obliged to suppose on the hypothesis that they had been brought along with the quartz-pebbles. On the other hand, the circumstance that many of the last-named are angular may perhaps be ascribed to the fact that hardly had they been split into fragments when they were enveloped in a precipitate of gelatinous silica, laden with iron sulphide, which will have formed around them, and sealed them up.

to the conglomerates and hardly occurs at all in the intervening sandstones, one must be prepared to admit the influence of some mechanical agency directed to the commingling of the gold and pyrites, as heavy constituents, with the larger pebbles, as seems to have happened in the case of all gold-bearing alluvial deposits. One may further observe that the transition from conglomerate to sandstone in a series of sedimentary deposits is either directly connected with some earth-movement or with a change in the system of marine currents (which may also have been brought about by earth-movements), and we may suppose that a movement of this kind would each time cause sulphurous or chloride-laden springs to well out, replenishing the metalliferous particles in solution in the water.

On this hypothesis it becomes easy to explain the presence of crystalline pyrites side by side with rolled pyrites, either by recrystallization (a by no means uncommon phenomenon), or rather by the fact that a number of pyrites-grains will have been precipitated direct, and will have escaped the action of the waves. Nor is there any reasonable objection to the supposition that waters charged with metallic salts may have permeated the beds previously deposited and covered over by the sea; these waters no doubt infiltrated more readily through the larger interstices between the big pebbles and precipitated the substances held in solution on to these. At all events the surfaces of the pebbles must have exerted a precipitating influence, so that on them the deposit must have formed, just as one so often notes is the case with pebbles placed in ferruginous or lime-charged waters, which soon become coated with rust or with carbonate of lime. Neither is the precipitation of gold from solution difficult to realize, and there is no necessity for invoking the presence of a reducing agent in the shape of organic matter (although examples of the kind have been shown to occur at Buffelsdoorn, at the Orion mine, etc.). Gold is precipitated from its solutions by all manner of agencies, and the only difficulty is which to choose among them all.*

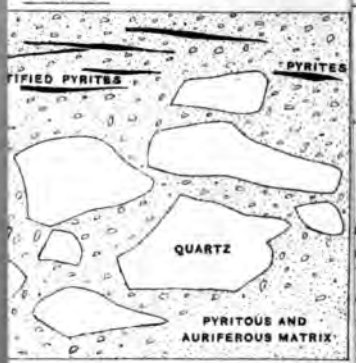
Finally, the primary origin of the gold may be ascribed either to thermal springs holding gold and silica in solution, such as those which caused the formation of auriferous vein-quartzes; or, if one will, to the erosion of veins of this kind, followed in the present case by chemical solution, instead of being the result of purely mechanical agencies.

* We may fairly claim in support of this notion a fact upon which Dr. Koch has laid great stress (see Prof. Schmeisser, *loc. cit.*, page 50), and which he discovered in the course of his microscopical studies, namely, that the free gold in conglomerates is not drifted gold, but gold crystallized by a secondary phenomenon after having been in solution.

attractive at first, although he felt compelled to abandon it, by the frequent occurrence of rolled pyrites in the ores. This postu the pyritous and auriferous impregnation occurred subsequen deposition of the conglomerate, quite independently of the n origin of its pebbles, but having some relation with their di physical structure, and arrangement.*

Even on this hypothesis it is impossible to suppose that interval between the deposition of the pebbles and that of the ous matrix can have been very long, since, in the case of the there is scarcely any room for doubt that the auriferous forn contemporaneous with sedimentation, and one hardly finds ancient pebble-bed wherein the pebbles have not been already together by silica. But in this case we need only presuppose of sulphurous waters, instead of a whole series; we are able to a the repeated localization of the gold in small conglomera between the quartzites and the shales (the junction with a giving always a favourable line for the circulation of waters) are in a position to explain how the auriferous inflow was inde the nature of the pebbles, which are considered to have mer the part of a filter whose constituents do not furnish any n they should of themselves contain gold. The localization of t the pebble-beds would then come about, simply because the int them are more widely opened to the percolation of mineral water the case with those in the sands now forming the quartzites finally, if one were to admit some relationship between the go eruptive rocks, or between the tenour in gold and the dip of these phenomena would be of equally simple comprehension.

FIG. 6.



ENTIRE THICKNESS OF THE SOUTH
LEVEL OF THE WOLHUTER.
OF THE PEBBLES IN THE QUARTZITE,
NCE OF THE STRATIFIED PYRITOUS ZONES.
ION THERE IS A GRADUAL PASSAGE
OMERATE INTO QUARTZITE.

Scale 2/3.

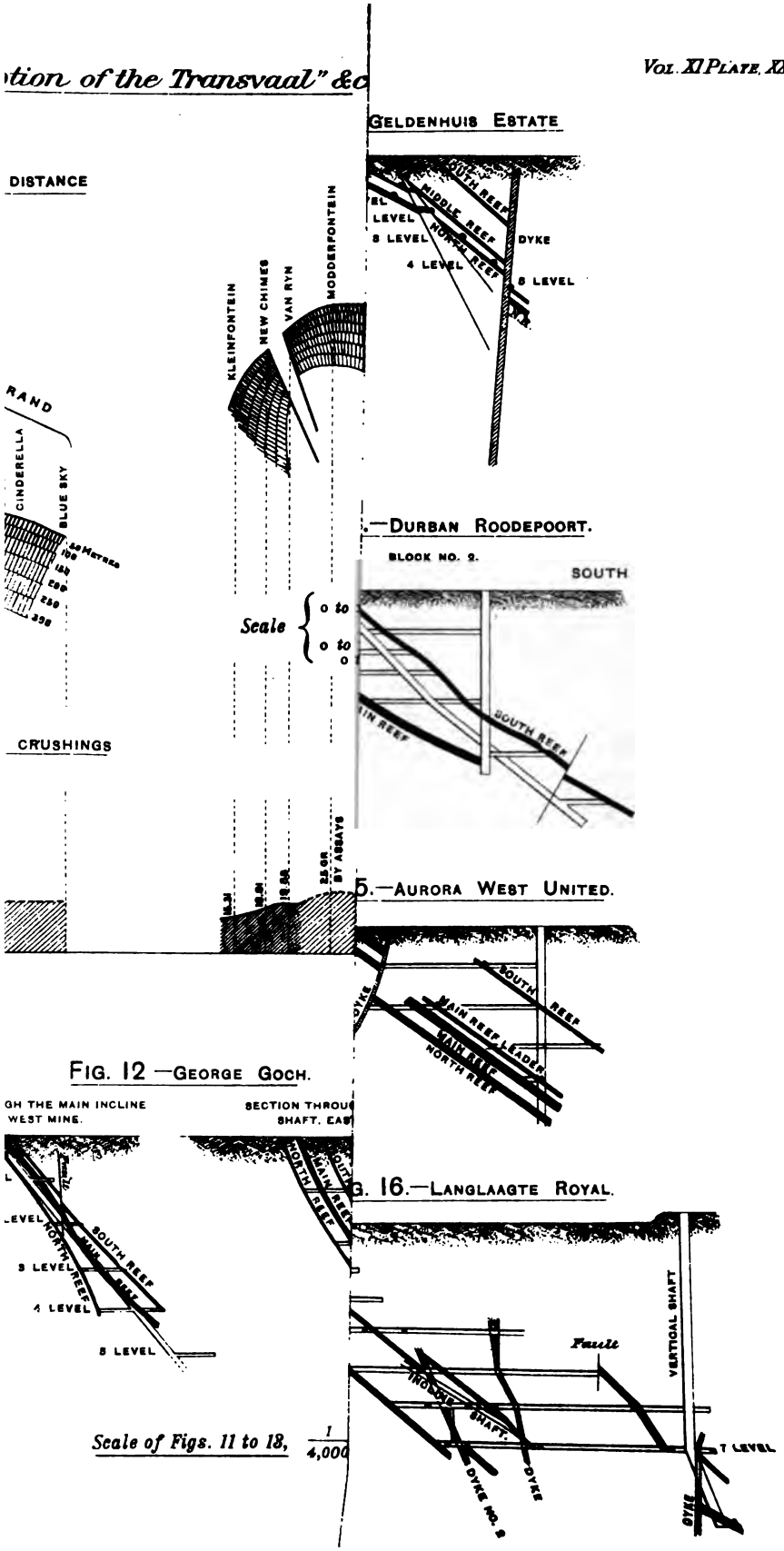
TO FIG. 5.

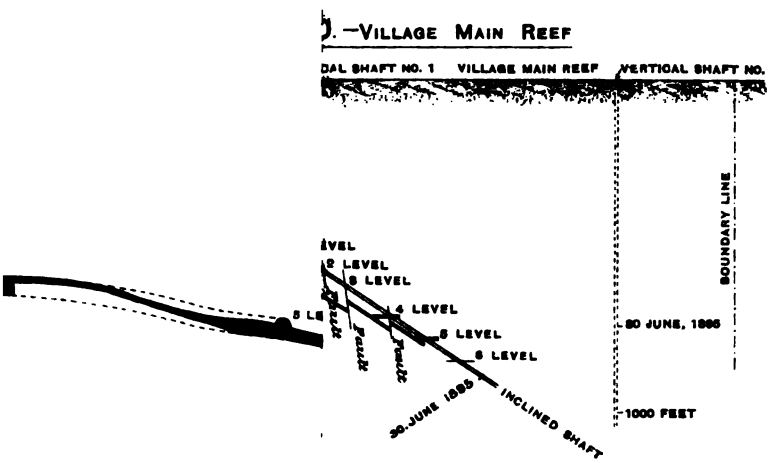
REEF OUTCROPS.
—— WELL KNOWN.
----- UNCERTAIN.
M.R. MAIN REEF SERIES.
K.R. KIMBERLEY REEF SERIES.
B.R. BLACK REEF SERIES

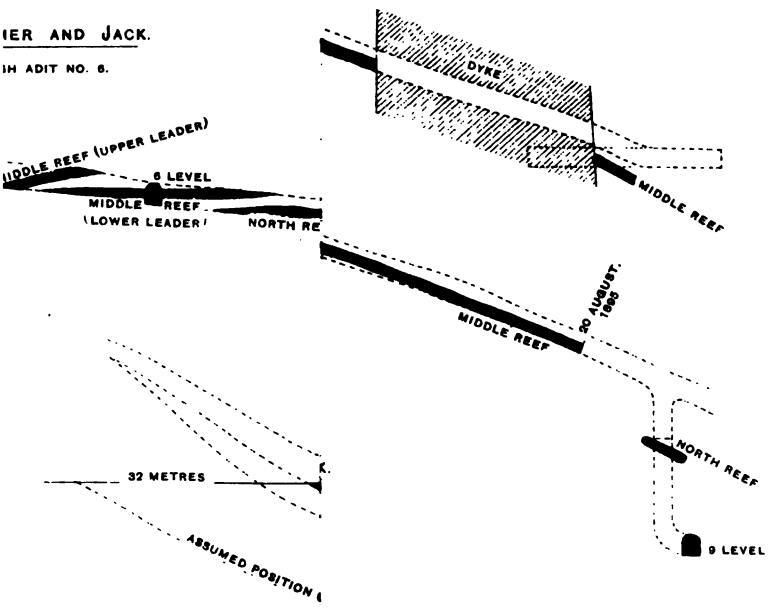
AND, HEIDELBERG, KLERKSDORP, ETC.
ER'S MAP).

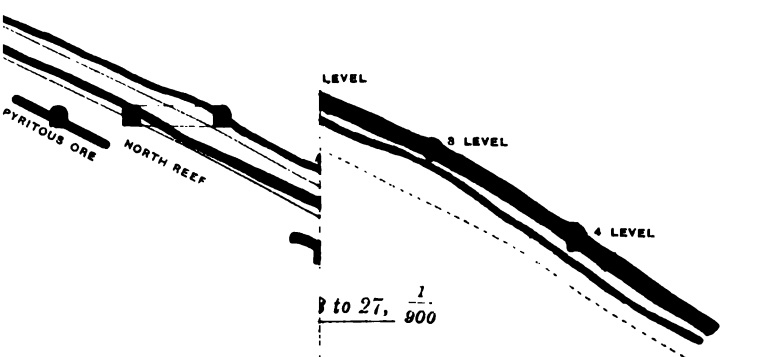
OF PRETORIA

FIG. 4.—GEOLOGICAL SECTION FR[illegible] TO THE VAAL RIVER. Scales { Horizontal, 1/202,792 ; Vertical, 1/38,460


GELDENHUIS ESTATE
DISTANCE
SOUTH REEF
MIDDLE REEF
DYKE
LEVEL
3 LEVEL
NORTH REEF
4 LEVEL
5 LEVEL
KLEINFONTEIN
NEW CHIMES
VAN RYN
MODDERFONTEIN
RAND
CINDERELLA
BLUE SKY
—DURBAN ROODEPOORT.
BLOCK NO. 9.
SOUTH
Scale
0 to
0 to
SOUTH REEF
CRUSHINGS
5.—AURORA WEST UNITED.
DYKE
SOUTH REEF
MAIN REEF LEADER
MAIN REEF
NORTH REEF
FIG. 12 —GEORGE GOCH.
GH THE MAIN INCLINE
WEST MINE.
SECTION THROU
SHAFT. EAS
NORTH REEF
SOUTH MAIN REEF
3. 16.—LANGLAAGTE ROYAL.
LEVEL
NORTH REEF
SOUTH REEF
MAIN REEF
3 LEVEL
4 LEVEL
5 LEVEL
Fault
VERTICAL SHAFT
CROSS CUT
SHAFT.
DYKE NO. 2
DYKE
DYKE
7 LEVEL
Scale of Figs. 11 to 13, 1/4,000







to 27, $\frac{1}{900}$

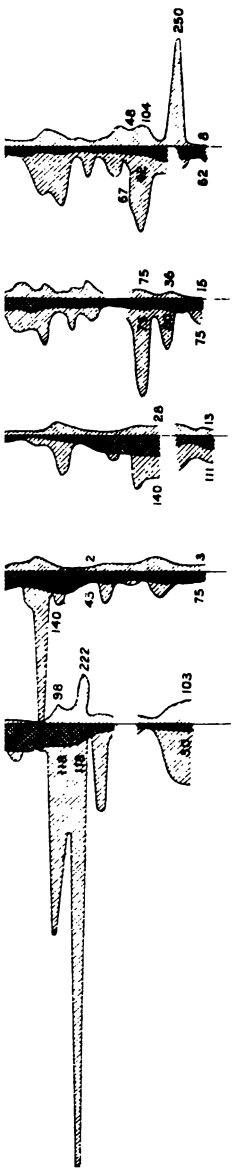
PLAN,

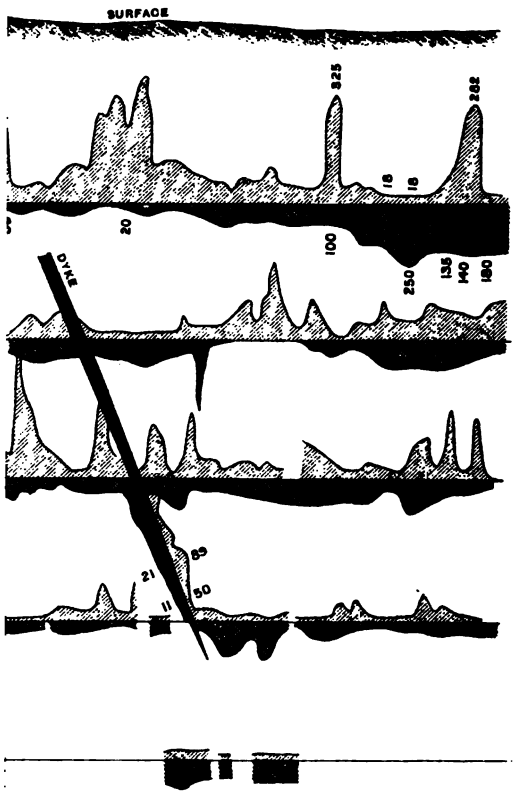
NTATION OF AN ASSAY-PLAN,
REEF.

LY TO THE SAME MINE.

IR OF GOLD IN GRAMMES PER TON

HE THICKNESS OF THE REEF IN CENTIMETRES.





Scales, { *Length of the Galleries,* 1/2,500 ; *Spaces between Galleries,* 1/1,250

This third hypothesis, however, has the drawback that it does not clearly explain why beds containing pebbles of the same size and identical as to physical structure are, a few feet apart, some of them auriferous and others barren. Nor does it explain why the auriferous pyrites is confined to a certain number of particular beds instead of being disseminated all through them, just as the physical conditions of the conglomerate may determine. In the case of vein-deposits which are true veins, metalliferous veins cutting across the bedding from end to end are always numerous, but we do not know of any examples of them in the deposits under discussion.* Lastly, perhaps the most decisive objection is that this hypothesis is irreconcilable with the frequent occurrence of rolled pyrites.†

To sum up, the first and third hypotheses are met by two objections which appear to the writer too cogent to be ignored: on the one hand, against the idea of a simple placer-deposit, we must set the fact that none of the pebbles, however big, ever contain gold;‡ on the other, the theory of posterior impregnation does not tally with the constant presence of rolled pyrites. Thus we are driven back on the second hypothesis, that is, chemical precipitation of the gold and pyrites during the actual process of sedimention.

---

* One can hardly class among such veins the few white quartz-veins with pyrites which form locally lenticles of small extent, and almost invariably barren, in the midst of the ore-deposits.

† It is true that the question might occur to the observer as to whether the pebbles of rolled pyrites may not have a perfectly distinct and independent origin from that of the crystalline pyrites. But this would seem to add useless complications to the hypotheses put forward, especially in view of the fact that the two kinds of pyrites show all the marks of intimate association one with the other.

‡ It would be interesting, moreover, to enquire what was the *locus* of the auriferous veins whose eroded outcrops could furnish these enormous quantities of the precious metal.

DISCUSSION ON MR. F. G. SHAW'S PAPER ON "THE GOLD-FIELDS OF MATABELELAND."*

Mr. THOMAS H. MOTTRAM (H.M. Inspector of Mines, Glasgow) wrote that Mr. Shaw appeared to take a very hopeful view of the future of gold-mining, and mining generally, in Matabeleland. Owing no doubt to the work of exploration and consequent discoveries being of so recent a date, he (Mr. Mottram) did not find the position of the Belingwe, Sinombi, and Guanda districts marked on the latest plan. He thought that the Guanda district lay south of Bulawayo, but it would be interesting to know the position of these districts in connexion with Bulawayo. It would seem that the matter of transport, though difficult and expensive as it must be until the railways are extended, is not so great a drawback as the unsettled state of the country occasioned by the recent rising of the Matabele. The distance from the present railway-terminus to Bulawayo is under 500 miles, and this distance is to be reduced by one-fifth by the extension from Mafeking to Gaberones, which is expected to be opened in the course of two or three months, and according to the last report of the British South Africa Company this railway is to be continued to Palapye and thence to Bulawayo.

It is refreshing to find that the result of the sinking of the sixty-two shafts referred to by Mr. Shaw is of so satisfactory a nature. Members who have read Lord Randolph Churchill's book *Men, Mines, and Animals in South Africa* will remember that at one time the reports upon the reefs in the Mazoe River district north of Salisbury, Mashonaland, were in many instances disappointing. Lord Randolph Churchill described how, after the visitation of many mines worked by the ancients, the reefs, though rich more or less at the surface, pinched out to nothing at a depth of 25 to 30 feet. According to more recent reports, however, upon the work of exploration in Mashonaland the mining progress is, in most cases, of a satisfactory character, though whether this means that the pinching out does not occur in all instances he (Mr. Mottram) is unable to say.

As regards Matabeleland, in the Belingwe, Sinombi, and Guanda districts, where, as Mr. Shaw describes, the reefs not only exist to a depth of 400 feet, but continue strong even at that depth, and although the ancients have worked somewhat extensively principally at or near the

* *Trans. Fed. Inst.*, vol. xi., page 29.

surface, any disagreeable doubts there may have existed in the minds of engineers will, no doubt, be removed by the work done by Mr. Shaw, and the great hopes entertained by others as to the mineral wealth of the country have been by his operation justified to a considerable extent. And yet only a small area, comparatively speaking, has been explored, and members have reliable testimony of the existence not only of gold but copper, lead, coal, mica, and other minerals in other parts of the country.

The plentiful supply of water and wood, the salubrity of the climate, the rapid construction of railways east, west, and north, the probability of there being an ample supply of native labour, these together with the favourable conditions granted by the chartered company enabling the owner or pegger of the outcrop to follow the reefs to any depth he chooses, will undoubtedly, as soon as the Matabele trouble is settled, induce a vigorous development of the whole country.

The PRESIDENT moved that the thanks of members be accorded to the Institution of Civil Engineers for the use of their rooms, and to the gentlemen who had so kindly opened their works to the inspection of the members.

The motion was agreed to.

Mr. H. PALMER (Consett) proposed a vote of thanks to the President for his services in the chair.

The motion was agreed to.

The meeting then terminated.

The following notes record some of the features of interest seen by visitors to works, etc., which were by kind permission of the owners open for inspection during the course of the London meeting, on June 4th, 5th, and 6th, 1896 :—

DEPTFORD STATION OF THE LONDON ELECTRIC SUPPLY CORPORATION, LIMITED.*

The members of The Federated Institution of Mining Engineers have previously visited the large supply station of the London Electric Supply Corporation, Limited, at Deptford, during the General Meeting held in London in May, 1891.†

At that time the supply of electric energy from this station had only been in regular operation for a comparatively short time, and as in the interval several large additions have been made to the plant, another visit will probably be of considerable interest.

The London Electric Supply Corporation, Limited, possessing Parliamentary powers for supplying electric energy over a large portion of London, originally started work with a central station at the Grosvenor Gallery, in London itself, making use of the alternating-current system of distribution. The difficulties connected with, and the expenses of, working a station in a town are, however, considerable, due to the increased cost of coal, the expense of carting coal to, and ashes away from, the station, and the liability to stoppage of the works by injunctions obtained by neighbouring property-owners on account of noise, vibration, or smoke. These considerations soon induced the corporation to seek for fresh premises outside the Metropolitan area, where they would be able to obtain their coal cheaply, be free from interference from sensitive neighbours, and be able to erect a station on a scale which would enable them to supply a largely increased demand for electric current.

A suitable plot of land of about 3 acres was eventually found at Deptford, near the Greenwich Hospital, having a large river-frontage, which gave the necessary facilities for obtaining sea-borne coal at a minimum cost.

Owing to the large amount of energy which was to be transmitted several miles to supply current in London, it was necessary to employ a high pressure, in order to reduce as far as possible the amount of copper in the main cables. After a considerable number of experiments the alternating-current system of supply was adopted, at a pressure of 10,000 volts—a pressure far in excess of anything hitherto dealt with, and even at the present day higher than any in use elsewhere.

* The illustrations are reproduced by permission from the *Engineer*.

† *Trans. Fed. Inst.*, vol. ii., page 439.

The employment of such a pressure required every detail of the scheme to be most carefully thought out; no existing apparatus was capable of withstanding such a pressure, and it therefore became necessary to design and produce special cables, transformers, switches, and dynamos to meet the case.

The success with which the many difficulties were successively overcome, and the perfect manner in which each part of the system worked, did much to advance the general principles of electric engineering, and have rendered this station one of the most interesting from a historical point of view.

The interest in the station is not, however, by any means confined to the way in which the high electric pressures have been successfully handled. In this station are to be found the largest dynamos in this country, and until quite recently the largest machines in the world. At a time when manufacturers were found making dynamos capable of developing 200 to 300 electrical horse-power as their largest powers, Mr. Ferranti designed, and put into successful operation, dynamos capable of developing 1,000 kilowatts, or 1,350 electrical horse-power, at the high pressure of 10,000 volts.

The ease with which high-tension electric currents have been dealt with at this station, with the special apparatus in use, has done much to popularize the high-tension alternating-current system of electric distribution—a system by which alone large quantities of energy can be transmitted economically over any considerable distances, and which renders possible the removal of the generating-stations for electric supply from the central parts of towns into the surrounding country, where the plant can be economically worked without causing annoyance to the inhabitants of the town.

The employment of large units of power in central stations is, too, becoming general. The small demand for current, met with in the early stages of this industry, rendered it necessary for economical working that the several engines and dynamos should be of comparatively small size, in order that during the long hours of small demand, one or two engines and dynamos could be run at or near their full output, when their mechanical efficiency is as high as possible. With the increase in demand, however, the loss in efficiency, due to running a number of engines and dynamos, as well as the increased cost of doing so, both in upkeep and in labour costs, at once become apparent, and at the present time all new stations are laid out on the plan originated by Mr. Ferranti at Deptford, of having one or two small units for the light-load day supply, and large units for the hours of heavy demand.

It is interesting also to notice in this station the great economy in space which is effected by coupling the dynamo direct to the shaft of the engine, and using the revolving part as a fly-wheel to increase the steadiness of running, over the older method of driving the dynamo from the engine fly-wheel by means of ropes or belts. The existence of a flexible connexion between the engines and dynamos, which is provided by the use of belts or ropes, is an advantage in some cases where the dynamos are run in parallel, that is, are made simultaneously to feed into the same system of main cables, when the running of the engines is not steady, or when the turning moment at different points in the revolution of the engine is sufficiently different to be incapable of equalization by the engine or dynamo fly-wheel, as is the case in two-cylindered single-acting engines.

With properly designed engines, however, either with two or three cylinders, there is no difficulty in running the dynamos in parallel when direct coupled to the engine, and owing to the special excellence of the Ferranti fly-wheel dynamo under these circumstances its use is becoming almost universal in this country.

The general arrangement of the machinery in the Deptford station is shown in Fig. 1 (Plate XXVI.). At the northern end of the plot of land is the coal-wharf, provided with the necessary cranes for rapidly handling and unloading the coal, which is then transferred direct to the boiler-house.

The boiler-house stretches right across the northern end of the station, and the chimneys are situated one at each end of the house. There are at present twenty-four boilers of tubular type, each of 500 horse-power, capable of working up to 200 lbs. per square inch pressure, divided into four batteries of six boilers each ; but provision has been made for placing a similar set of twenty-four boilers arranged in the same manner on the concrete floor above the present boiler-house. The chimneys, which are 26 feet by 18 feet, are each divided into four separate flues, each flue being connected with one of the sets of six boilers, so as to completely subdivide the boilers into separate units. The gases from the boilers pass through Green economizers on their way to the chimneys. Beneath the present boilers is situated the forced-draught engine, to facilitate making steam rapidly in case of a foggy day.

To the south of the boiler-house are situated the engine-rooms. The first engine-room, on the east of the central avenue, contains two small Ferranti dynamos, each giving an output of 225 kilowatts, or 300 electrical horse-power, and driven by two sets of triple-expansion condensing engines,

each of which is capable of developing 350 indicated horse-power, at the normal speed of 150 revolutions per minute, and driving the dynamos by rope-gearing at a speed of 300 revolutions per minute.

The second engine-room, on the eastern side of the central avenue, separated from the first by pillars only, contains two Ferranti dynamos, each giving an output of 500 kilowatts, or 670 electrical horse-power, driven by two horizontal tandem, compound, single-crank, Corliss engines, each indicating, at full load, 750 horse-power. These engines run at 65 revolutions, and drive the dynamos at 250 revolutions per minute by means of seventeen 5¼ inches ropes. These dynamos were originally in use at the Grosvenor Gallery station, and were removed to Deptford on the closing of that station.

The dynamos give a pressure of 2,500 volts, which is then raised by transformers to 10,000 volts for transmission to London, the transformation for each machine being effected by four transformers, each capable of dealing with 150 horse-power. The machines are separately excited, or magnetized, by continuous-current dynamos built by Messrs. Siemens. For examination of the armatures, screw gear is provided for sliding back the two halves of the magnet-frame until the armature is left exposed.

The third engine-room, that on the west of the central avenue, adjoining the boiler-house, contains two large Ferranti dynamos of 1,000 kilowatts each. These two large dynamos are of 1,500 horse-power, and generate current at 10,000 volts. The diameter of each armature is 13 feet, and the height of the machine from the bed-plate 14 feet 6 inches. Each machine possesses forty-eight armature-bobbins, which are copper strips wound on a core of insulated brass strips, and connected in pairs. New ones can be replaced on the armatures in a few minutes– a characteristic which is found in all the Ferranti dynamos. On the faces of the field-magnets are fixed two ebonite caps. Each tested to 20,000 volts, they thus prevent sparking from the armature to the frame of the machine.

Special attention has been paid to the effective lubrication of all parts of the machinery. At the end of the shaft, of each 1,500 horse-power dynamo, is a double set of pumping gear, which, drawing the oil from tanks underneath, forces it into the bottom of the bearings, the oil afterwards passing through a filter back into the tank. A hollow chamber is fixed round the bearing of the dynamos, through which cold water circulates freely.

By means of special machinery, the field-magnet frames of the dynamo can be drawn back for cleaning in less than ten minutes. The exciting machines (Allen and Kapp dynamos) are placed at the rear of the large

dynamos; they are of slow speed—200 revolutions, 50 volts, and 400 ampères each. By means of special switches they can be connected to any of the dynamos, or run in parallel, ampèremeters and voltmeters on each machine indicating the exact state of each exciter.

This may be a fit place to mention that all the machines are now run in parallel. Formerly, when changing the load at the Grosvenor station from one dynamo to another, the lights blinked, which caused customers to complain. Since, however, running in parallel, the load is transferred without the least flicker.

The engines driving the large dynamos are of 1,500 horse-power, and of the vertical marine Corliss type. The driving power is transmitted by forty 5 inches ropes on a fly-wheel 22 feet in diameter, weighing 60 tons. The stroke of the engine is 4 feet. The low-pressure cylinder measures 56 inches, and the high-pressure 28 inches in diameter. A special valve-gear is employed on these engines, and by means of a wire rope the man in charge of the switch-board can open or close the valve at pleasure. Swivel-bearings are employed on all the dynamos and engines.

The second engine-room, on the western side of the building, contains the latest addition to the plant—a direct-coupled set, consisting of a Ferranti dynamo, capable of developing 1,000 kilowatts, illustrated in Figs. 2 and 3 (Plates XXVI. and XXVII.).

The dynamo is directly attached to the crank-shaft of the engine, no flexible coupling being used, the shafts being rigidly connected by means of 9 bolts, each 2 inches in diameter. The machine has been designed for an output of 1,000 units, *i.e.*, 100 ampères at 10,000 volts; but ample provision has been made for the safe working of all parts up to 11,000 volts, and during the progress of the trials the machine was fully tested up to 12,000 volts when running at its normal speed—156 revolutions, and periodicity 83 per second. No difficulty whatever has been experienced in working the new unit in parallel with any of the other dynamos in the station, and it is proved that it can be put into parallel even with the smallest, and withdrawn without the production of any irregularity in the continuity of supply.

The dynamo shaft carrying the fly-wheel, which in its turn also carries the armature, is supported by two spherical bearings, 12 inches in diameter and 36 inches long, made of cast-iron and lined with white metal; each bearing is provided with a separate pump for lubrication, the oil being forced in in a manner which in previous experience has proved effective and economical when dealing with heavy bearings. The end-thrust is taken up by means of collars on the shaft—a most impor-

tant point in connexion with machines of this design, wherein the clearance between the armature and the pole-pieces of the field-magnets must necessarily be severely small. The standards upon which the bearings are mounted act as storage-chambers for the lubricant, and the one on the engine-side of the armature also acts as a rigid connexion between the base-plate of the engine and the dynamo.

The armature-wheel, or fly-wheel, is 26 tons in weight, of which 14 tons are in the rim; it is secured in position by shrinking two hoops over the boss of the wheel, which is bored a dead fit to the shaft. The wheel proper consists of two castings, each having four arms of H section, each arm being independent at the boss. When mounted in position, the joint of the rim is secured by shrinking on two mild steel hoops of massive section, over machined projections from inside of the rim. The wheel is further strengthened by eight tie-bolts 6 inches in diameter (minimum section), which are screwed into a mild steel casting shrunk on to the centre of the shaft; these bolts are heated, after being screwed up, and being again screwed down, are given a definite tension.

The wheel has been designed, firstly, to have a large factor of safety when working at a peripheral speed of 7,800 feet per minute, while supporting an armature which by its own weight increases the centrifugal force by nearly 30 per cent.; and, secondly, to run perfectly true.

The armature is insulated and supported in the manner usually adopted by Mr. Ferranti. Cast-steel nuts are held in cored recesses in the fly-wheel rim by means of sulphur compound, and from these insulated steel bolts project through the rim to support the armature. The bolts are insulated by ebonite cured on before machining is completed, and each bolt can thus be tested before being used in construction; 32 pairs of these bolts support the armature, the 64 coils of which are held in pairs between bronze holders; the coils of bare corrugated copper strip are wound on cores of corrugated brass strip separated by asbestos, burnt together into a gun-metal block. Each pair of coils is mounted in its holder, into which it is riveted under a hydraulic press, the result being a very mechanical armature, having no loose wires or connexions.

The insulation of the coils, owing to the above construction, is a comparatively simple matter. Each pair of coils, generating 620 volts, is insulated to withstand this pressure with ample margin, the whole armature being mounted on the insulated bolts, which have to withstand the full ordinary working pressure of 10,000 volts. The outside diameter of the armature is 22 feet, and thus the peripheral speed is 11,000 feet per minute.

The field-magnet frame consists of eight castings, in which are mounted 128 field magnets, 64 on each side of the armature, and they have a total weight, with field-poles and copper, of 37 tons. The field-coils are wound with bare copper on edge, which system secures the maximum copper in a given space with the best radiation. The pole-faces are protected by means of caps made of micanite.

For cleaning and other purposes, a 1 unit motor is provided, which separates the two field-magnet frames, driving separating-screws by means of gear-wheels, five minutes being taken to open or close the machine.

The following are the leading particulars:—Height of machine from floor line, 14 feet 6 inches; overall length, 24 feet; width from outside pedestal to engine-coupling, 12 feet 6 inches; copper loss in armature, 0·85 per cent.; copper loss in field-magnets, 1 per cent. The total weight of alternator, with beds, shafts, and fly-wheel, is 80 tons. Before being used for commercial purposes the armature of the machine was tested standing with the field-magnet frames at working distance with 21,000 volts at 83 alternations, corresponding to 30,000 volts direct current.

The engine consists of three separate compound engines set tandem fashion over a three-throw crank-shaft, the cranks being set, as in a triple-expansion engine, at angles of 120 degs. Each engine is complete in itself with its own jet condenser, steam-pipe, stop-valve, oiling-gear, etc., and is guaranteed to indicate 500 horse-power, with an initial steam pressure of 140 lbs.; but as all working parts have been designed for a much greater strain, and as the boilers at Deptford can be worked, and are worked when necessary up to 200 lbs. pressure, it is clear that these engines are capable of indicating together 2,000 horse-power.

The three high-pressure cylinders of the engines under notice are $16\frac{1}{2}$ inches in diameter, the low-pressure cylinders being 27 inches, and the stroke of all is 26 inches, so that there is ample room for the development of the required power.

There are no stuffing-boxes on the piston-rod between the two pistons, the best type of corrugated rod having been adopted, and this has been found to give complete satisfaction. Steam is admitted to the high-pressure cylinders by means of piston-valves, and the low-pressure cylinders are fitted with ordinary flat-valves. Each pair of valves—high and low-pressure—is driven by a single eccentric, eccentric and valve-rods, the latter being well guided in a heavy bracket fixed just below the low-pressure valve-chest, and all variation of speed is controlled by means of

Joy gear, which is fitted into the body of each eccentric, and by means of which the stroke of the valve is varied as may be required. This effect is produced by the forcing hydraulically of the centre of the eccentric into either full-gear ahead or into any position between that and mid-gear. The crank-shaft is of best mild Siemens-Martin forged steel, 10½ inches in diameter, and is made in three interchangeable lengths coupled together, and the cranks are double-webbed.

Each low-pressure cylinder exhausts down its back column, and the steam meets the condensing jet on its way down, the injection-valve, which is controlled from the front of the engine, being attached to the column. The air-pumps are placed behind the engines, each one being driven by a pair of levers from the crosshead, and means have been provided by which the air-pumps can be quickly disconnected, should it be found necessary, owing to failure of water, breakdown, or other cause, to work the engines non-condensing. Two valves have been fixed to the eduction-pipes of each low-pressure cylinder, by means of which the exhaust steam can be passed down to the condenser and air-pump, or allowed to escape into the atmosphere.

The water necessary for the supply to the condensers is taken from the river at high water into a large storage-tank (Fig. 1, Plate XXVI.), constructed on the wharf behind the boiler-house; but as this only holds 600,000 gallons of water, and cannot be filled during neap-tides, a well has been sunk to a level below that of low water, and from this well it is anticipated that a large augmentation of the condensing water supply will be effected. The whole of the condensed steam and condensing water are returned to the river, the impurities in the river water rendering it useless for boiler-feeding, and evidently the difficulties in the way of cooling the condensed water for use again are either insuperable or too costly. Had it been possible to cool the discharge from the condensers of the station, so that it might be used as injection and as boiler-feed without fear—for the reservoir could be filled with fresh water to begin with—a great gain in efficiency would have been made.

The current from the dynamos is taken to the main switchboard. Each of the 10,000 volts machines is controlled by means of five levers arranged on the platform, as in the signal-box of a great railway station; the parallel between the Deptford switchboard and a railway signal-box, indeed, is made more forcible from the fact that the levers are exactly on the model of those in use on the railways. One of the levers actuates the main dynamo switch, placed high above the attendant's head; three are used for the purpose of moving the resistances in the field-magnet

circuit of the alternator, and the purpose of the fifth is to break or connect the leads between the exciters and the field-magnets. These five levers are the only part of the gear ever touched in the ordinary way of working when the machine is on load, and as all these levers are permanently connected to earth, it is impossible that they should at any time become charged to a dangerous potential.

The full bay to the left of the switching-gear is occupied by the ends of the four trunk-mains to London and their apparatus. The mains come up through the insulated platform, and each main is provided with a pair of fuses 4 feet 6 inches in length. The fuses are carried in a tube built up of two lengths of porcelain pipe, which are joined by means of a short piece of tube made of toughened glass, and which allows of examination of the fuse by the electrician on duty, the lower half of the tube being filled with sand. The advantages of having two fuses in parallel on each main are many, but the principal use is that it enables the man in charge to alter the strength of the fuse without affecting the continuity of supply, and to prevent the occurrence of any accident due to the insufficiency or over-sufficiency of the fuse for the amount of current passing at the time.

Between each pair of mains are the plugs and general arrangements for connecting or disconnecting them from their work. Owing to certain effects due to the length and capacity of the mains, it is not possible to put on a main or withdraw it from work suddenly without producing what will be sufficiently indicated as a disturbance to the equilibrium of the system. For some years the difficulty has been overcome in a satisfactory manner by the use of a main discharger.

Hitherto it has been the practice at Deptford to run all necessary mains, machines, and distributing-stations in parallel, but as such a system involves certain evils, the new main switching-gear has been provided with a large central switch, worked by a lever on the platform, by means of which it will be possible to divide the mains into two pairs and allow of the parallel system of supply being broken—one machine or bank of machines supplying current through Nos. 1 and 2 mains to the Grosvenor and the Belgravia distributing-stations: while another machine or bank, not in parallel with the first, supplies the Blackfriars and Trafalgar stations through Nos. 3 and 4 mains. From experience it has been found that during heavy loads this will be a great advantage, not only in the economical use of the dynamos and engines, but also in that, should any accident occur on one half of this system, the other will not be affected.

…pply Corporation, Limited."

oly Corporation, Limited."

From the switchboard the current is conveyed to London by the special mains designed by Mr. Ferranti, and made under his supervision. In order to produce the necessary insulating properties required to withstand the high pressure of 10,000 volts, Mr. Ferranti made use of paper insulation. A continuous length of chemically-pure brown paper is rolled on to a length of about 20 feet of copper tube, having the desired sectional area of metal, until the proper thickness of insulation is obtained. The paper is saturated while it is being wound on with a special composition (consisting mainly of ozokerite or earth-wax) in a melted state, which sets very quickly. The paper thus treated forms the insulating-material between the inner tube and the outer tube, which is then slipped on and drawn down through a die, tightly compressing it on to the insulator. The tubes are of the same length and sectional area.

The outer tube is then covered in the same manner as the inner, and, to prevent this outer layer of insulation being damaged, the entire cable thus formed is fitted into an outer tube of iron, which serves the purpose of a thorough mechanical protector.

The current is received at the London end of the mains at sub-stations, of which that in Trafalgar Square may be taken as a typical example, and there transformed down from 10,000 to 2,400 volts for distribution.

WORKS OF THE ELECTRIC-WELDING COMPANY, LIMITED, 21, HINDON STREET, PIMLICO, LONDON, S.W.

The Thomson electric-welding system is making considerable progress in the development of electric-welding in this country.

The apparatus as generally used to carry out the Thomson process consists of:—

(*a*) An alternating-current generator.

(*b*) A welding-transformer, provided with clamps and mechanical appliances to work the heated metal.

(*c*) Electric regulating-apparatus to control the flow of current (thereby enabling the heat in the metal to be varied).

The generator produces electricity at 300 volts, the welding-transformer reduces this voltage in the ratio of about 300 to 1, as the pressure used in the welding circuit is only about 1 volt, and it is perfectly harmless to the operator.

The Thomson process is most suitable where the objects to be welded are of fairly even cross-section, but Mr. Wallis-Jones has recently successfully welded uneven sections (*i.e.*, 1 inch to ½ inch) by first heating the larger one. The welds may be either butt or scarf joints.

The Thomson welding process consists in passing an electric current of great volume, by means of two clamps of good conducting metal (usually copper), through two pieces of metal firmly abutted against each other between the clamps, and when heated by the current, the pieces are forced together by mechanical pressure. The metal between the clamps alone possesses the requisites for the conversion of electrical energy into heat. The only loss of energy is that caused by conduction of heat to the clamps of the apparatus, by radiation, and the resistance-loss in the electric generator and welding machine. By increasing the speed of the operation, the first two sources of loss, which are alone of importance, will be greatly reduced.

The Thomson process of electric-welding differs from all others, either forge or electrical, inasmuch as large volumes of current are forced through the metal to be electrically heated, and because its own resistance is sufficient to bring every molecule of the section traversed by the current to the desired temperature. In all other methods, such as the forge, gas blow-pipe, electric-arc, etc., the heat is not generated in the metal or joint itself, but always either in the surrounding envelope and communicated to it through conduction, or in the contact between the metal and another high-resisting medium as in the Holo process.

In the Thomson process, heat is generated in the metal itself at the joint to be welded, and is not communicated to it.

In other processes in which heat is transmitted from the outside, the surface to which the heat is applied is the hottest, and the core or interior where the heat is wanted is the least hot. In the Thomson electric process, the core, which is best protected from radiation, first becomes heated.

By this electric-welding process:—

(*a*) Practically all the energy or heat can be utilized.

(*b*) The rate of heating can be increased or decreased at will; and

(*c*) All further loss of heat can be stopped by simply removing the metal pieces from the circuit.

The variety of uses to which this method of welding can be applied is almost endless. A brief statement, however, of a few of the applications are as follows:—Copper, brass, iron, steel, etc., wires may be joined. Chains may be made of links of single or double welds, as may be desired. Pipes of all kinds may be joined end to end, forming non-leaking joints. General welding in engineers' shops, such as spindles, shafting, rods, bars, winch-handles, combination steel tools, brazing, etc. Uniting steel with iron drop forgings or castings. Welding together various grades of steel in tool manufacture. Repairing tools and finished work without damage. Lengthening or shortening bars, screws, or bolts. Welding wire-rope cables, etc., for tramway and other purposes. Welding steel-rims for pneumatic and rubber tyres for cabs, carriages, etc., and other sections which have hitherto been brazed on account of the difficulty of welding them by hand. Electric-welding has also been successfully applied in the manufacture of cycle frames, pedals, etc.

The apparatus, used for welding purposes, may also be employed with suitable clamping devices for electric soldering, brazing, shaping, forging, riveting, and bending of metals. The following are a few of the results which may be thus produced:—Coiling steel springs for various purposes. Twisting iron or steel for tools or other uses, and bending and twisting chains and links into desired shapes, or making sharp joints or angles accurately situated in bars or shafts. Straightening bent shafting or bars. Locally annealing tempered pieces, or hardening steel or iron pieces, locally or otherwise. Heating pieces to be pressed into shape while hot and in the clamps, including moulding heads on bolts, upsetting shoulders or collars on shafts, axles, or spindles. Shaping bars or tubes into desired forms. Welding new lumps on to gun-barrels, etc. Riveting in difficult positions, and heating the head of the rivet only, where desired.

The special advantages of the electric-welding process are:—

(1) The homogeneous nature of the welding, the structure of the metal at the joint being the same as elsewhere in the parts welded.

(2) Absolute control over the heat, for by simple appliances the metal can be held at any temperature desired for any length of time, and localization of heat at the joint.

(3) The welding process can be continually watched, as the metal while heating is visible, instead of being covered with coal or hidden by flame as in the forge process.

(4) The weld commences at the interior of the joint, and not in an uncertain way as in ordinary lap-welding, and consequently any flaw in the process can be easily discovered and prevented.

(5) The process is almost instantaneous with small diameters of metal, while with larger sizes it requires but a few seconds, depending upon the horse-power used.

(6) The process may be applied to various kinds and forms of metal, including those which have heretofore been united only by brazing.

(7) Complicated forms can be held in well-defined relation towards each other during and after the welding process.

(8) Oxidized surfaces are excluded from the joint, but clean metal comes into welding contact.

(9) The welding operation can be, and often is, made automatic, thus securing uniformity of result.

(10) Pieces can be welded to exact size, and finished pieces may retain their finish during welding.

(11) The cost of fuel is about the same as in ordinary forge-welding, while the cost of labour is reduced one-half, and is accompanied with economy of material.

(12) Prevention of blistering, scaling, or other injury to any portion of the metal.

(13) By using the necessary transformers, incandescent lamps can be run from the constant potential dynamos whenever the current is not required for welding purposes.

The strength of the welds made by the Thomson process of electric-welding has been tested by Dr. A. B. W. Kennedy, who reports the following results:—In the case of wrought-iron, the ratio of the strength of the welded to that of the unwelded bar was 89 per cent., this being the mean of welds on bars varying from $\frac{1}{2}$ to 2 inches in diameter. In the case of Bessemer steel, the ratio of the strength of welded to solid bar was no less than 96·5 per cent.

WATERLOO AND CITY RAILWAY.

Fig. 1 (Plate XXVIII..) shows the route taken by the Waterloo and City Railway from Waterloo Station to near the Royal Exchange, where an underground station will be built. It commences under Waterloo Station, where the rail-level will be 36 feet below that of the South-Western Railway. The arrival and departure-platforms will be at right angles to those of the South-Western Railway, and extend under that part of the station covered by platforms Nos. 1 to 6, and beyond No. 1 towards the South Station. There will be staircases and inclined passages from different parts of the present Waterloo Station to the one below. The line will be prolonged past the end of the platform to the south side of James Street, abutting on the Lower Marsh. From this point to Aubyn Street, a distance of about 350 feet, will be placed the terminal, or shunting-sidings, together with the generating-station, including engine-house, boilers, flues, etc.

The South-Western Railway Station is really built on an immense viaduct, of which the piers pass through some 16 feet of made ground, consisting of black mud, into ballast. These piers will all be underpinned, where they are above the new line; which will, at the station, have two separate arches, one for the up and the other for the down line. There will be inverts under these arches consisting of four or five rings of ordinary bricks set in cement; the inverts serving not merely to distribute the pressure, but to keep back the water with which the soil at this part is permeated.

From No. 6 South-Western platform, the new line begins to curve to the right till it passes clear of the station, just under No. 10 platform, where cross girders will be provided between the side-walls to carry the piers. This part of the construction will be cut-and-cover work, combined with underpinning. The regular tunnel work commences at the eastern side of the Waterloo approach, just before Cross Street, and close to the general offices of the South-Western Railway Company.

The railway consists of two parallel tunnels, and as a rule the horizontal distance between the outsides of two tubes will be about 4 feet, but soon after leaving Waterloo Station it becomes necessary to reduce this to 2 feet at the point where it passes under the Charing Cross and Cannon Street branch of the South-Eastern Railway Company.

At the commencement of the line, the two tunnels will be on the same level. The gradient, as far as the end of the first curve, will be 1 in 710, rising towards the City. Thence the tunnels drop at 1 in 60

to the South-Eastern Railway bridge. Here the levels of the two tunnels vary: the up or western line descends at an inclination of 1 in 30 for 900 feet, whilst the other, or down line, continues at 1 in 60. The object of this rapid descent is to sink one line as soon as possible out of the water-bearing ballast into the impervious clay. It will be observed that this incline of 1 in 30 is with the load, the steepest gradient against the load at any part of the line being 1 in 60. At the end of the 900 feet length the up tunnel falls 1 in 120 to Broadwall, and then 1 in 800 to the shaft. The other tunnel has a regular descent of 1 in 550 from Broadwall to the shaft, whence they run both on the same level to the City Station.

From the shaft, the lines are level for a length of 100 feet, and then rise 1 in 800 for 1,300 feet, to a point opposite the *Times* office. The rise for the rest of the line is 1 in 88 to the commencement of the station, which will be between Queen Street and Bucklersbury, under the roadway at the upper end of Queen Victoria Street, close to the Mansion House. The City station platforms will be 330 feet long, and beyond them there will be a single shunting line, 300 feet long, rising 1 in 100. The rail-level will be 65 feet below the surface, with which it will be connected by a 1 in 9 inclined subway and stairs.

The construction of the tubes is shown in Figs. 2, 3, 4, and 5 (Plate XXVIII.). Each section is 20 inches long, consisting of seven segments, and a key-piece at the top. The longitudinal joints are planed radial to the centre of the tunnel, excepting the sides of the key-pieces, which are parallel and vertical, so that they may be inserted more easily. The segments are joined together, and the separate sections are also connected by means of turned bolts, 1 inch in diameter. No packing is placed between the segments, but between each section there is a strip of creosoted wood, from $\frac{3}{8}$ inch to $\frac{1}{2}$ inch thick.

From the shaft towards the City, the internal diameter of the tubes is 12 feet $1\frac{3}{4}$ inches, and the external diameter 13 feet; but towards Waterloo, in order to ensure that the carriages shall not foul the sides in passing round the 5 chains curves, the internal diameter is 12 feet 9 inches, and the external 13 feet $7\frac{1}{4}$ inches. The horizontal distance apart is in both cases 17 feet 6 inches from centre to centre, except where they have to be brought closer together at Cross Street, as previously described.

Connexions are made between the up and down lines for the convenience of platelayers, etc., at intervals.

It was decided that the whole of the excavations should be made from a staging in the river near the Surrey shore, just below low-water mark

(Figs. 6 and 7, Plate XXVIII.). The distance of the centre line of the railway from Blackfriars Bridge, at the point where the shafts were sunk, is about 500 feet. The staging is 325 feet long by 50 feet wide; the first pile was driven on June 20th, 1894, and the stage was finished in November.

A connexion with the shore is made by means of a foot-bridge from 15, Upper Ground Street; but all spoil is removed, and the cast-iron rings, and all other materials, are brought to the site by water. The stage in the river not only serves as a starting point for the shafts, but carries the engines, dynamos, air-compressors, cranes, offices, and stores.

In August, 1894, the sinking of the shafts was commenced. The shafts consist of cast-iron cylinders, 16 feet in internal diameter, and they were sunk into the bed of the river until they had entered the clay to a depth of 13 feet. When the contents of these cylinders had been excavated, the sinking of the shafts was continued. This lower part was lined with brickwork, the first 10 feet being 1 foot 6 inches thick, followed by 17 feet of 2 feet 3 inches thick, which reached to the bottom of the tunnels. The upper part of the brickwork is circular, like the cylinder; but the section is gradually changed, so that at the bottom, the shafts have two flat sides, at right-angles to the axis of the tunnels, the section being very nearly a square with rounded ends. This part of the work was finished early in October, and the shields for driving the four faces were then lowered in pieces, and put together at the bottom of the shaft.

On November 26th, 1894, the up tunnel was started towards the City, and on December 10th the other side of the same tunnel was commenced. The City end of the down tunnel was commenced on January 16th, 1895, and towards Waterloo on the 28th.

Figs. 8, 9, and 10 (Plate XXVIII.) show back view, section, and front view of the Greathead shields used between the shafts and the City. The two for the up and down tunnels between the shafts and the Waterloo end are identical, except that they are 7¼ inches greater in diameter than the one shown in the illustrations. The front of the shield is formed by a heavy cast-iron ring, made in four segments, with flanges for bolting together. A steel cutter, 1 inch thick, in eighteen segments, and forming a continuous conical ring, is secured to the casting by set screws, and projects 2¾ inches in front of it. At the back of the casting is a ¾ inch wrought-iron diaphragm, fitted with a rectangular opening, 6 feet 6 inches high by 5 feet 6 inches wide. Behind the diaphragm is another cast-iron ring, in seven segments, each of which carries the steel

cylinder of a hydraulic ram, each 7 inches in diameter by 22 inches stroke. The back ends of the piston-rods are fitted into steel castings, which bear against the last finished ring of the tunnel. By means of a circular tube from the hydraulic-main, the same pressure can be exerted by all of the rams ; or by working some of the presses and stopping others, the direction of the shield can be varied as may be desired. When the pistons of the rams are out to their fullest extent, they are protected from any dirt or stones that might otherwise fall on them by a cylinder formed of two $\frac{1}{4}$ inch steel-plates which surround the shield, and extend backward over the finished portion of the tube : $\frac{1}{8}$ inch clearance being left between the outer side of the cast-iron ring and the inner side of the steel-plate.

Whether working under compressed air or not, a heading is always excavated and timbered in advance of the shield. The size of this heading varies according to the nature of the ground; whilst in the clay, and before using compressed air, it is 7 feet high by 5 feet wide in the clear. The timbering for this is composed of 4 inches by 11 inches head-trees, 3 inches by 11 inches side-trees, and hard wood foot-blocks 9 inches by 9 inches by 3 inches. The shield, except when a change of direction is necessary, is pushed forward equally by all of the hydraulic presses for a length of 20 inches. The seven segments and key-piece, which form a complete ring, are then lifted into place and bolted up. The weight of each complete ring is 1·81 tons for the larger, and 1·73 tons for the smaller size.

As a rule, whether working under compressed air or not, two complete rings can be put in per shift whilst working in clay, but with a full face of ballast the maximum progress has been one ring per shift. Towards the City, where the tunnels are wholly in the clay, three rings have been done by the day and three by the following night-shift, which gives a progress of 10 feet in twenty-four hours, and this progress has been maintained for some time. The number of men at a face is 13, and when compressed air is used there are the lock-keepers in addition. The total number of men employed on the works is about 200.

Directly a ring is in place, grouting, composed of 3 parts of blue lias lime to 1 of sand, is injected through holes left in the centre of each plate by means of the grouting apparatus. This consists of an iron drum, in which the lime and sand are mixed with water; and then, whilst a handle is continually turned, to keep the mixture homogeneous, air at a pressure of 50 lbs. to the square inch is admitted, and the grouting is thus forced through a hose into the vacant space behind the ring, which it completely fills.*

* *Trans. Fed. Inst.*, vol. ii., Plate XL., Fig. 5, page 438.

When working near the shafts, the spoil was shovelled into skips, which stood on low platform waggons, pushed by hand to the shafts, hoisted by steam cranes to the platform, and emptied into barges. As the tunnels advanced, another form of skip, without handles, was used. The haulage is now done by means of three electric locomotives, made by Messrs. Siemens Brothers & Co., and especially designed for this work. The current is supplied from the dynamos at the top of the stage. Figs. 11 and 12 (Plate XXVIII.) show side and end elevations of one of these locomotives. The line is worked on what is known as the double-trolley system, with an effective pressure or difference of potential of about 200 volts. The wooden block which carries the two insulators is bolted to a transverse flange of the tunnel tube, two of the holes for bolting the sections together being used for that purpose.

The gauge of the line is 18 inches, and the locomotives are designed to haul a load of 5 tons at a speed of 7 miles per hour on the level, and 3 miles per hour on a gradient of 1 in 60. Each locomotive is fitted with a Siemens H. B. 8/10 motor, carried upon a strongly-built wrought-iron frame, and geared to the driving-wheels, which are coupled by means of double reduction—bevel and spur—gearing, enclosed in an oil-tight case. A rod, attached to one of the brake levers, operates the starting and regulating-switch by means of a rack and pinion, so adjusted that it is impossible to apply the brakes whilst the current is on. This arrangement also enables the locomotive to be driven from either end with equal facility. The regulation is accomplished by means of resistance-steps in the usual way. There is also a reversing-switch, a main-current emergency-switch, and fuses of the double-pole type. To the reversing-switch is geared a lamp, which turns so that it always exhibits a red light in the direction in which the locomotive is travelling. Instead of a whistle, there is a pneumatic signal horn. The whole is covered by a galvanized sheet-iron canopy, and there is a sand-box, which is found useful on the gradients.

The air-lock consists of a wrought-iron cylinder, 5 feet 9 inches in internal diameter and 13 feet long, made of $\frac{1}{2}$ inch plate stiffened with T-iron rings. A brick wall, 6 feet 2 inches thick, is built across the tunnel; and into this wall not only the air-lock, but the various pipes are built. These consist of a 12 inches pipe for materials, a 12 inches air-main, a 2 inches compressed air-pipe, a 2 inches water-pipe for grouting, a 3 inches water-outlet for drainage, if necessary, a 2 inches pipe at the top for the electric pump, telephones, and electric lighting wires; and a spare pipe 6 inches diameter, with a blank flange at either

end. This last pipe has been provided as an extra precaution in case of an accident to any of the other conduits. The air-main is carried along the completed portion of the tunnel near the top, supported by wrought-iron brackets bolted to the flanges. The tube for materials has a clear length of 30 feet between the valves. The doors of the air-lock are of cast-iron, 1¼ inches thick, stiffened all round with webs. They both open towards the pressure, so that they must remain closed whilst the pressure is being equalized. Valves for regulating the pressure can be worked either from inside or out: when workpeople pass through it is necessarily worked from inside, and is so set that the change must take at least 1¼ minutes; but when only trucks are being passed, it is more rapid.

Compressed air was used when passing under the Metropolitan District Railway, between the Temple and Blackfriars Stations, and for 100 feet on either side, extending from the Embankment, opposite the Royal Hotel, to the centre of New Bridge Street.

As it was not likely that compressed air would be needed at any other portion of the line between Blackfriars and the City, one air-lock was provided for both the up and down lines. The air-lock was placed in the up tunnel; the down tunnel being closed by a solid brick bulkhead, pierced only by the air-main. Parts of three rings were removed from the sides of both tunnels, and between them a temporary opening was built, through which a line of rails was laid connecting those in the two tunnels. By this means, one air-lock served for both lines, and when the 100 feet limit had been reached, bulkheads and air-lock were removed.

At the Waterloo end of the down line, the use of compressed air was commenced at the same date as at the other end (May 22nd, 1895), the pressure being about 7 lb. or 8 lbs. per square inch. As this tunnel is nearer to the water-bearing ballast, which covers the clay, than any of the others, and will be the first to enter it, timbering was at once commenced. The heading, which is kept two rings in front of the rest of the excavation, is 6 feet by 3 feet in the clear, the top of the head-tree being level with the top of the shield. Small piles are driven ahead horizontally into the clay. From the centre downwards there are poling-boards, 1½ inches thick, for 4 feet 6 inches on each side. These are carried by leg-boards against the face, the tops being cut to the sweep of the shield. The leg-boards stand on 11 inches by 4 inches waling, which is strutted against the front of the shield, at a height of 6 inches below the top of the door. When this part of the timbering is in place, the excavation is continued below it for about 4 feet, when a second

waling is placed across and strutted against the front of the shield as before. Poling-boards are then placed from the upper to the lower waling. Finally, the excavation is continued down to the level of the bottom of the shield. In order to be able to remove the struts between the shield and the walings, which serve to keep the latter in their places, two upright timbers, 11 inches by 4 inches, known on the works as "soldiers," are placed against the walings, and a beam, 10 inches by 10 inches, is placed right across the tunnel, three rings back, and is wedged firmly against the sides. From this cross beam, two raking struts are placed against the centre of the soldiers, and wedged up tight. The temporary struts or stretchers from the shield to the walings are then struck, and the shield is pushed forward for 20 inches. One ring is inserted and grouted, and then the shield is moved forward for another 20 inches, and another ring is put in place. As soon as this has been grouted, the excavation and poling proceed as before for another 40 inches.

By varying the thickness of the wooden packing placed between the complete rings, it is possible to direct the course of the tunnel as may be desired. On a 5 chains curve, radial segments have been necessary, as the sections are 1 foot $8\frac{13}{32}$ inches wide on the outer, and 1 foot $7\frac{19}{32}$ inches on the inner radius.

The tubes, when completed, are to be lined with concrete; and this part of the work is being done at present down to the level of the temporary rails. The mixture used is 1 part of cement to 6 of ballast; but for filling in the key-piece, the proportion of cement is increased, and sand is used with fine ballast. A special apparatus has been made for filling these top pieces. A box with wooden sides, and a false bottom of sheet iron, is hung by stirrups from the bolts. This box, before being placed in position, has been filled with the exact amount of concrete which one key-piece will hold. Two rollers, worked by a lever handle, raise the false bottom, so as to cause the concrete to enter the key-piece. The plate is held up by pins passed through the stirrups; then, the wedges being removed, the sides of the boxes are withdrawn, but the stirrups and plates are left up for twenty-four hours. From the floor-level, up to 20 inches above the centre, the concreting is done with boards in the usual manner, and for filling the last 20 inches cross-lagging is used. The joints between the sections are pointed with a mixture of three parts of Portland cement to one of fine sand.

At the stations at both ends of the line, the two tubes will run into one, which will have a diameter of 23 feet.

The up Waterloo tunnel is now under York Road, and there are 8 feet of ballast at the face. The adjacent tunnel has not been proceeded with since the early part of the year, and is now completed as far as Cornwall Road. Going towards the City, the two tunnels have reached the eastern side of Cannon Street: as they are of the smaller section, greater rapidity of construction is possible, and a speed of three rings per shift, or 10 feet per twenty-four hours, is being maintained.

The deck of the stage is 7 feet 3 inches above high-water mark. The machinery carried on it comprises one 5 tons, two 3 tons, and two 2 tons cranes; four 100 horse-power boilers of locomotive type; three dynamos of 100 volts and 112 ampères; one dynamo of 200 volts and 112 ampères; and two 250 horse-power air-compressors. The compressed-air receivers are placed under the staging.

Messrs. W. R. Galbraith and J. H. Greathead are the engineers, Mr. Dalrymple-Hay is resident engineer, and Messrs. Wales and McDonnell assistants, in charge of the works for the Waterloo and City Railway Company.

The work is being carried out by Messrs. John Mowlem & Co. Mr. William Rowell is contractors' agent, and Mr. Chas. Campbell contractors' engineer.

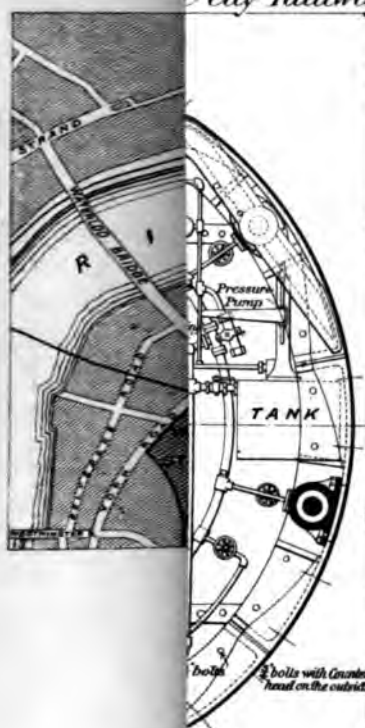
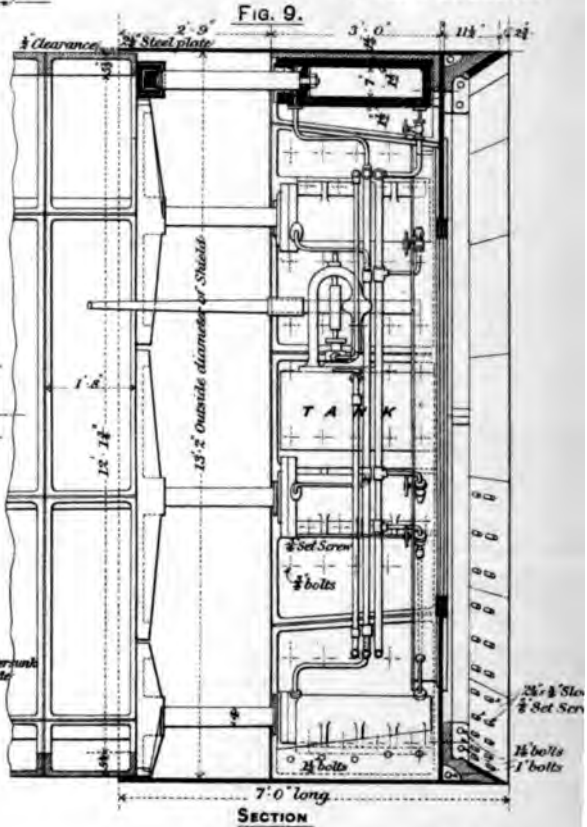


FIG. 9.

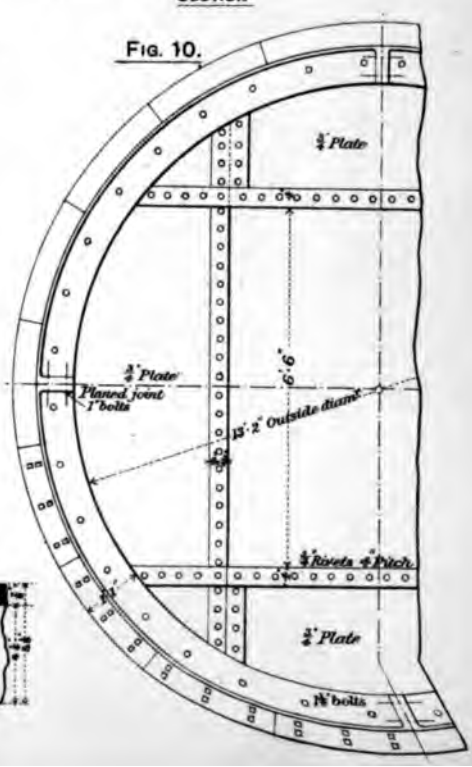


SECTION

FIG. 3.

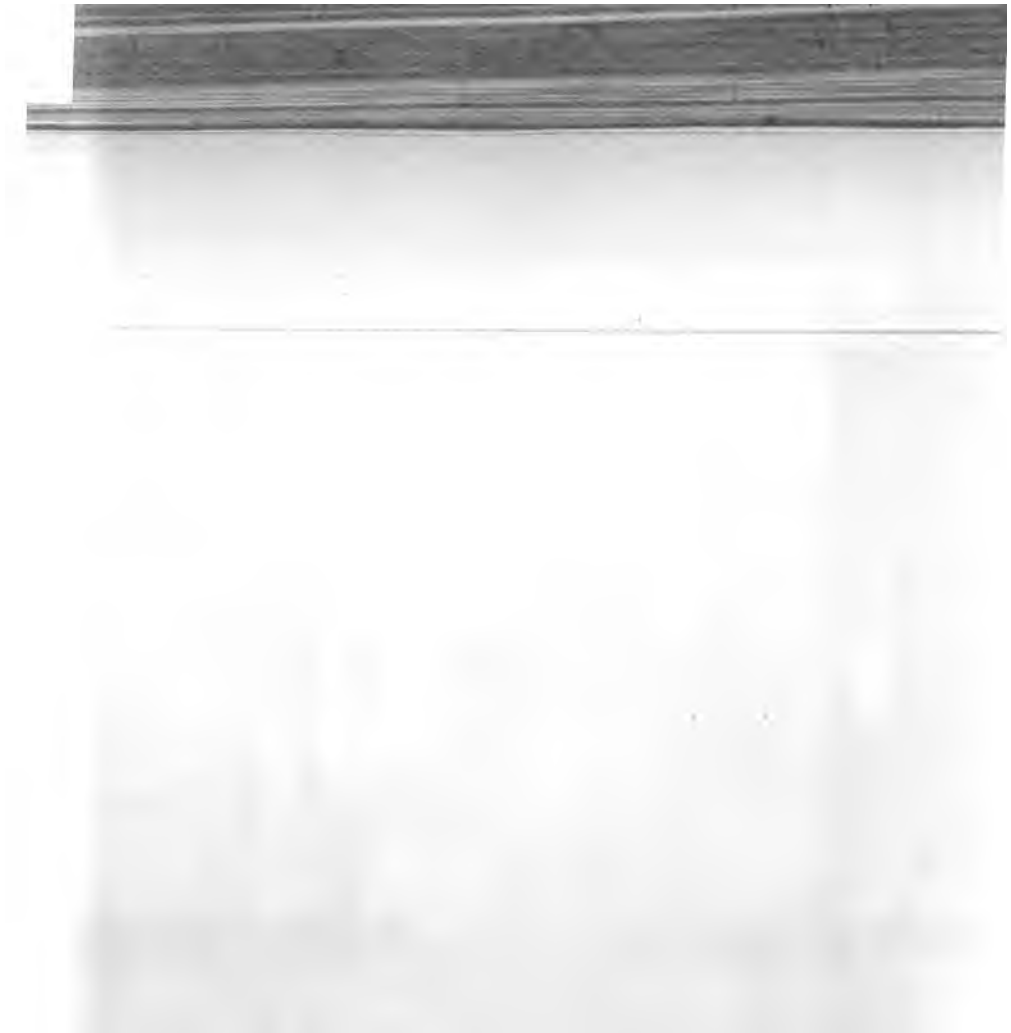
NGITUDINAL SECTION

FIG. 10.



G. 5.

UMFERENTIAL JOINT



THE MÜLLER SMOKE AND GAS-MASK.

On December 13th, 1894, a pit-fire, arising from spontaneous combustion, was discovered in one of the headings of a German coal-mine, and two manual-pumps were at once got to work, and on cooling the walls with water, the seat of the fire could be seen at a distance of about 100 feet. As the air was irrespirable, special precautions were necessary, and only one man at a time, and then protected by a smoke-mask, could be employed in extinguishing the burning coal.

Although the seat of the fire could have been approached from two sides, it was only advisable that the work of extinguishing should be carried on from one side, and that, with the help of the mask, on the side which was exposed to the current of bad air. For this purpose one of the manual-pumps which had previously been used for pumping water was attached to the air-tube connected with the mask, and placed —in such a position that the air was pure enough for the workmen operating the manual-pump—in the heading in the direct course of the ventilation. Under ordinary circumstances, the wearer of the mask, supplied with fresh air, could have worked for several hours, but as the temperature of the fire to which he was exposed exceeded 150 degs. Fahr. he was consequently obliged to retire every 30 to 45 minutes, and could only return to his work after rest and refreshment.

The great advantage of the Müller smoke-mask is that only a few workmen are required to carry out dangerous work. Formerly, in similar cases, twenty to fifty and even more men, according to the distance of the seat of the fire, were required to carry utensils and materials for damping the fire, as they could only proceed in single file, and when they reached their goal were obliged to retire at once for fresh air, often requiring the services of those coming after them to help them to a place of safety.

The mask is made of doeskin, in the shape of a fireman's helmet, fitted round the lower edge with a pad which is placed over the shoulder, and is fastened under the arms by a chain and a spring. The face is protected by a double-wire gauze of about 900 meshes to the square inch, large enough for the egress of air and to allow the wearer to see and hear, but too small to admit flame, smoke, or fire-damp. Below the wire-gauze is the inlet for fresh air, to which the tube is fixed. The air should be supplied by a pump or bellows of about 8 inches diameter.

The main points to be observed are :—

(*a*) That the pump or bellows be placed where the air is free from smoke or foul air, and that the air-pump be worked energetically and continuously, for which purpose two men must be told off for work and relief.

(*b*) That the mask be fitted on by an assistant before the wearer leaves the neighbourhood of the pump.

(*c*) That the wearer shall not leave the pump before he feels the current of pumped air entering the mask, and that the pumper shall not discontinue pumping until the wearer of the mask has returned to the pump.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE HARVEY INSTITUTE, BARNSLEY, JULY 22ND, 1896.

MR. JOHN NEVIN, RETIRING-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

Messrs. W. Sutton and R. Holiday were appointed scrutineers of the voting-papers for the election of officers, and of the balloting-papers for representatives on the council of The Federated Institution of Mining Engineers for 1896-97.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. FREDERICK BOULDEN, Lecturer in Engineering, Sheffield Technical School, Sheffield.

Mr. RICHARD BRANCKER, Colliery Proprietor, 39, Cannon Street, Liverpool.

Mr. SAMUEL CLOUGH, Mechanical Engineer, Micklefield Colliery, near South Milford.

Mr. PETER SINCLAIR HAGGIE, Engineer, Gateshead-upon-Tyne.

Mr. WILLIAM ARTHUR HARGREAVES, Surveyor, Micklefield Colliery, near South Milford.

Mr. WILFRED MARSHALL HARROP, Mechanical Engineer, Princess Street, Morley, near Leeds.

Mr. GEORGE CROSBY, Colliery Manager, Croft House, Featherstone, near Pontefract.

STUDENT—

Mr. JOHN NEAL, Jun., Mining Student, Middleton, near Leeds.

The Annual Report of the Council and the statement of accounts for the past year were read as follows:—

THE COUNCIL'S ANNUAL REPORT.

The Council have pleasure in presenting to the members of the Institute their report on the work of the past year.

The number of members for the past two years is as follows:—

	1894-95.	1895-96.	Increase.
Life Members	4	4	—
Honorary Members ...	11	11	—
Members	210	223	13
Associate Members ...	7	10	3
Associates...	8	11	3
Students	6	9	3
Totals	246	268	22

Showing an increase of 22 in all classes over last year.

The Council desire to draw the attention of members, when proposing gentlemen for election to the Institute, to the rules applicable to the classification of candidates, which will be found at the back of the nomination-papers.

The following papers have been read during the past year:—

"Telephonic Communications in and about Coal-mines." By Mr. A. W. Bennett.

"Notes on the Sinking of the No. 1 Pit at the Ackton Hall Colliery, with Special Reference to the Thinning Out of the Silkstone and Beeston Coal-seams." By Mr. H. St. John Durnford.

"Obituary of Mr. Joseph Mitchell." By Mr. G. J. Kell.

"Electrical Machinery for Mines." By Mr. Rankin Kennedy.

"Method of Closing the Tops of Upcast Winding-Shafts." By Mr. Alex. Reid.

"The Roth Method of Firing Shots." By Mr. Geo. Blake Walker.

"Adjustable Piston-Rings." By Mr. H. Wormald.

The arrears of subscriptions for the year 1895-96 amount to £19 10s., as against £16 10s. last year; to the latter amount must be added £7 10s., balance of arrears for 1893-94, making a total of £24, which, in the opinion of the Auditors last year would prove a realizable asset. Of this amount, £18 has been paid, leaving a balance of £6, which has now been struck off as irrecoverable, leaving £19 10s. arrears for the past year to be dealt with: of this amount, £15 is estimated by the Auditors to be recoverable.

The Council have to record with deep regret the death of Mr. Thomas Carrington, F.G.S., M. Inst. C.E., and one of the past-Presidents of the Institute. Mr. Carrington was one of the leading mining engineers of the

district, a member of the Examination Board for Managers' Certificates, and a most energetic and popular member of the Midland Institute, whose interests it was always his endeavour to promote. The fact that Mr. Carrington's end was hastened by overwork and worry, has made his death a subject of special regret, and the Council have communicated to Mrs. Carrington and the family the sincere sympathy of the members of Institute. A memoir of Mr. Carrington will shortly be published in the *Transactions*.

There have been held during the past year six meetings, and the Council would call the attention of members to the fact that Students are admitted up to the age of twenty-five years. Further, that a series of meetings are arranged in connexion with The Federated Institution of Mining Engineers for the special benefit of the Students, and prizes are awarded for the best papers.

THE TREASURER (Mr. T. W. H. MITCHELL) IN ACCOUNT WITH THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS, 1895-96.

DR.

1895.	£	s.	d.	£	s.	d.
July 1.—To Balance at Bankers	42	8	10			
,, ,, Cash in Treasurer's hands ...	3	11	11			
				46	0	9
1896.						
June 30.—To Subscriptions for 1895-96 ...	342	0	0			
,, ,, ,, paid in advance for 1896-97	6	0	0			
,, ,, Arrears...	18	0	0			
				366	0	0
,, Sale of Dinner Tickets ...	10	3	6			
,, ,, Members' portion of the Wine Account at the Annual Dinner	0	18	0			
				11	1	6
,, ,, Sale of Authors' Copies of Papers and List of Members				2	2	0
,, ,, Bank Interest				1	18	5
				£427	2	8

July 17th, 1896.

Audited and found correct,

H. B. NASH, }
G. J. KELL, } Auditors.

CR.

1896.	£	s.	d.	£	s.	d.
June 30.—By The Federated Institution of Mining Engineers:— Call of 17s. per Member on 252 Members for 1895-96...	214	4	0			
,, By Balance of Call for 1894-95	1	14	0			
,, ,, Excerpt *Transactions* ...	5	0	5			
,, ,, Reducing Plates	5	10	0			
,, ,, Proportion of cost of Exchanging *Transactions* with other Societies	2	0	0			
				228	8	5
,, ,, Annual Dinner				15	13	0
,, ,, Printing and Stationery				13	10	0
,, ,, Office Rent				12	0	0
,, ,, Reporter				10	0	0
,, ,, Insurance				1	11	6
,, ,, Cleaning				0	11	0
,, ,, Gas Company				0	6	10
,, ,, Hire of Rooms for Meetings at Leeds, Sheffield, and Wakefield				2	18	6
,, ,, Secretary's Salary	£50	0	0			
,, ,, ,, Expenses ...	9	6	9			
				59	6	9
,, ,, Joiner-work				6	9	0
,, ,, Colour-washing, etc.				1	5	0
,, ,, Stamps, Telegrams, Carriage, Wrappers, and Sundries				15	10	4
,, ,, Balance at Bankers... ...	£50	12	4			
,, ,, Cash in Treasurer's hands...	9	0	0			
				59	12	4
				£427	2	8

Midland Institute of Mining, Civil, and Mechanical Engineers.

General Statement, 1895-96.

Liabilities.	£	s.	d.	Assets.	£	s.	d.	£	s.	d.
1896.				1896.						
June 30.—None.				June 30.—By Cash in Bank	50	12	4			
Balance, being capital	436	7	4	„ „ „ Treasurer's hands ...	9	0	0			
								59	12	4
				„ „ Estimated Value of Instruments for Fan Experiments				10	0	0
				„ „ Value of 6,752 parts of *Transactions*, at 1s. ...	337	12	0			
				„ „ Value of 119 Copies of Committee's Report on Safety-lamps, at 1s.	5	19	0			
				„ „ Value of 116 Copies of Narratives of Sudden Outbursts of Gas, at 1s.	5	16	0			
				„ „ Value of 16 Copies of Report of French Commission on Use of Explosives, at 3s. ...	2	8	0			
								351	15	0
				„ „ Arrears of Subscriptions ...	...		...	15	0	0
	£436	7	4					£436	7	4

July 17th, 1896.

Audited and found correct,

H. B. Nash, G. J. Kell, } Auditors.

The report and statement of accounts were adopted on the motion of Mr. J. LONGBOTHAM, seconded by Mr. E. W. THIRKELL.

ELECTION OF OFFICERS FOR 1896-97.

The scrutineers reported the results of the elections as follows :—

PRESIDENT:
Mr. GEORGE BLAKE WALKER.

VICE-PRESIDENTS:
Mr. A. A. ATKINSON. | Mr. E. W. THIRKELL. | Mr. J. E. CHAMBERS.

COUNCIL:

Mr. JNO. LONGBOTHAM.	Mr. J. MELLORS.
Mr. M. HALL.	Mr. J. R. ROBINSON WILSON.
Mr. H. B. NASH.	Mr. H. ST. JOHN DURNFORD.
Mr. W. HY. CHAMBERS.	Prof. F. W. HARDWICK.

SECRETARY AND TREASURER:
Mr. T. W. H. MITCHELL.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS, 1896-97.

Mr. A. M. CHAMBERS.	Mr. C. E. RHODES.
Mr. W. E. GARFORTH.	Mr. GEO. BLAKE WALKER.
Mr. JON. LONGBOTHAM.	Mr. F. N. WARDELL.
Mr. J. NEVIN.	

The CHAIRMAN said that he had much pleasure in vacating the chair to give place to Mr. G. Blake Walker. He begged to thank the vice-presidents, the council, and the members for the universal kindness extended to him during his period of office.

The PRESIDENT, on taking the chair, said that he accepted with great diffidence the nomination of the council to stand as President of the Institute. He asked the members to pass a hearty vote of thanks to Mr. Nevin, who, during the past few years, had ably occupied the chair, and attended the meetings with almost absolute regularity. Mr. Nevin had done much to foster the progress of the Institute, not only during his term of office of President, but for many preceding years during which he had been an active member.

The vote was carried by acclamation.

Mr. NEVIN, replying, said that he was much obliged to the members for their vote of thanks. His term of office had been a most pleasant one. He felt that he left the Institute in good hands, and he hoped that it would still go on in the path of prosperity, and that its usefulness and membership would alike increase. The members could not have any one better to lead them in that way than their new President, Mr. G. Blake Walker.

ELECTION OF OFFICERS BY BALLOT.

Mr. THIRKELL (Oaks Collieries) moved that Rule 9 be altered by adding in line 15 the words "the election of all officers shall be by ballot;" that the word "ballot" in lines 13 and 15 be substituted for the word "voting;" and that the word "signed" in line 16 be struck out.

Mr. W. HOOLE CHAMBERS (Tankersley Colliery) seconded the motion.

The motion was carried unanimously.

Mr. T. B. A. CLARKE read the following paper on "Electric Coal-cutting on Longwall-faces":—

ELECTRIC COAL-CUTTING ON LONGWALL-FACES.

By T. B. A. CLARKE.

The present position of the coal trade is so bad and the general outlook so gloomy that the study of any system which will lessen the cost of production will always be an acceptable one to those interested in coal-mining. It would appear in the light of events more or less recent that the price of labour itself in collieries is not likely to be materially reduced in the near future unless the miners modify their views with regard to certain economic tenets formulated by themselves and therefore at present dear to their hearts. Again, we gather from statistics published periodically that the collier of to-day does less work than his predecessors, and as this tendency has been continuous for a considerable period it is more than probable that unless some new system of coal-getting is employed many collieries will have to considerably extend their working-faces in order to maintain their output of coal. These considerations have led many mining engineers to regard the use of coal-cutting machines as a probable solution in many cases of the difficulties which for some time past have rendered the profitable working of many seams well nigh impossible.

It is not surprising therefore that a large amount of attention has for a considerable time been devoted to this subject, and with such good effect that coal-getting by machinery has been in successful operation for the last twenty years at a number of English and Scotch collieries.

Until about 1890, it was the universal practice to employ compressed air as the motive power. The lowness of the efficiency and consequent high cost of working have, however, greatly limited its use.

The rapid strides made in the applications of electricity as a motive power for all classes of mining machinery have marked it out as eminently adapted to this class of work, and though progress has, perhaps, not been quite so rapid as might have been expected, there can be little doubt that, where conditions are favourable for its use, electricity will henceforward take the leading place as a motive power for coal-cutting machines. A number of excellent papers on coal-cutting by air-driven machines have already appeared in the *Transactions* of The Federated Institution of Mining Engineers, and the members are doubtless well acquainted with the results obtained in the instances cited.

The writer proposes in this paper to describe briefly the method and apparatus employed in cutting coal electrically, to compare electricity as a motive power with compressed air, and to give some results obtained in seams of various thickness by electrically-driven machines. It is assumed that the members are more or less familiar with the principles underlying electric transmission of power. It is so generally used now at collieries for one purpose or another that the majority of the members will be conversant with the nature and relationship of volts, ampères, and ohms, in other words the units of pressure, quantity, and resistance.

The writer will now describe, somewhat in detail, an electric coal-cutting plant. We will assume that the seam is 3 feet thick, that the holing is carried 4½ feet under, and that 80 linear yards per shift are cut by each machine. We will also suppose that each machine cuts for two shifts each day—that is, 16 hours out of the 24—and that three machines are constantly at work. First, a few words as to the assumptions we have made. The standard of 80 yards per shift is based on the actual performances of the machines, to which the writer is specially alluding under the conditions postulated above. It will be found good practice to work the machines two shifts per day where the faces are of good length, the gates not too far apart, and where conditions are generally favourable for rapidly clearing the face after the coal is cut. The third shift can be utilized for doing any necessary repair on the machine, and periodically overhauling it generally—a practice always advisable. If the machines cut only for one shift per day, double the number of machines will have to be employed to get the required output, a larger generating-plant will be necessary, and more length of working-face will be required to give the best economical results. The depth of undercut of 4½ feet is the general practice nowadays in seams where the thickness is not less than 3 feet. In seams of less thickness than 3 feet, the difficulty of transporting a wheel over 5 feet in diameter has hitherto limited the depth of the undercut. The writer suggests the use of a cutter-wheel, split into two parts segmentally, which would effectually dispose of this difficulty.

On the above assumptions the machines will undercut 480 linear yards per day, producing between 600 and 700 tons of coal daily. Assuming that the faces are 400 yards long, the gates may be placed at such a distance apart that the coal already cut can be filled out in three days, for by that time the machine will be again cutting there.

We will consider first the engines for driving the dynamo. The type of engine most in favour at present for dynamo-driving is the vertical

high-speed engine, and in the writer's opinion this type offers many advantages over the horizontal engine for this purpose—in cheapness of first cost of engine, engine-house, beds, and repairs. Direct-coupled engines and dynamos effect, no doubt, great saving in space; but in this case, where the load will certainly fluctuate rapidly between wide limits, a belt is most useful in taking up and minimizing the sudden mechanical strains, which otherwise might ere long act prejudicially on the armature of the dynamo. Compound engines for this purpose will probably not find much favour, on account of the low steam-pressure in use at most collieries and the rapid fluctuations of the load.

For the above purpose the engine should indicate about 80 horse-power, and run at a speed of about 250 revolutions per minute. Two cylinders, 14 inches in diameter, 12 inches stroke, and worked with 40 lbs. of steam pressure in the cylinder, would give the requisite power. The cost of such an engine, with a suitable governor, would be about £380.

The dynamo for this purpose should be a compound-wound, preferably an undertype machine, that is with the centre of gravity of the moving parts kept low. It should be capable of working continuously at an output of 65 horse-power. At a speed of 600 revolutions per minute it should give 400 volts on open circuit, and 440 volts with a load of 120 ampères, that is, it should be over-compounded 40 volts to allow for loss of pressure in the line at full load. This is merely a matter of economy, and would be objectionable if the same dynamo were used for lighting; in that case larger-section cables would have to be used, and the loss in line thereby reduced. The points which are essential in the design of a dynamo for this purpose are:—(*a*) Mechanical strength; (*b*) thorough insulation; and (*c*) freedom from sparking under varying load. There is no difficulty in obtaining these conditions if the design and manufacture be carefully carried out by experienced people. The efficiency of the dynamo should reach at least 90 per cent. at full load.

The switchboard should be similar to any ordinary, well-designed electrical switchboard, and should have mounted on it a suitable ammeter and voltmeter, main double-pole switch, and main double-pole cut-out. The switch should have a break of at least 5 inches, and a carrying capacity of 150 ampères, the fuses should be constructed to fuse at this current, which is too low to cause injury to the dynamo unless continued for a considerable time. Its purpose is merely to protect the dynamo in case of a short-circuit on the main cables. In the branch

cables to the various machines double-pole fuses of 50 ampères capacity should be inserted at accessible points, and these will amply protect the various machines. The writer has tried automatic cut-outs actuated magnetically by the action of the main current passing round a solenoid, but found that they were uncertain and troublesome at a voltage of 400, and considers that the ordinary fusible cut-out of sufficient length gives by far the best results.

The cables used in this installation should be carefully selected to suit the conditions of the mine, and if this be done their life should equal that of any part of the plant. The cable which will be found equal to almost any conditions is the type insulated with pure and vulcanized rubber, and served with a strong protective covering of tarred hemp and braid. It is a good practice to use a standard insulation-resistance of 2,000 megohms per mile: the cost is very little more than if a standard of 600 megohms be used, and it is of the utmost importance that the insulation-resistance of the whole circuit should be as high as possible.

Concentric cable is being largely used in colliery installations, but for coal-cutting work it is, in the writer's opinion, by no means to be recommended, and two separate cables, though costing some 15 per cent. more, are preferable for the following reasons:—

1.—A short circuit is almost impossible, as the cables of opposite polarity can be kept any desired distance apart.

2.—Single cables are rapidly spliced and extended, and, in case of severe abrasion, re-insulated; in many cases it would be impossible to repair concentric cable, and it would need to be returned to the cable-maker, causing thereby great expense and inconvenience.

In fixing the cables in the shaft, they should hang vertically, the weight being taken every 15 yards by tying them to insulators fixed firmly in the shaft. It is not a good plan to make cables carry too much weight without support, as a heavy strain is put on the insulation which in time may cause serious trouble.

Along the roads belowground, the cables should be tied to insulators every 8 or 10 yards, tar-band should be used (not wire), and no great strain should be put upon them. If this plan be used, breakage of a cable will be almost unknown, a heavy fall of roof will simply sway them on to the floor without causing any damage further than surface-abrasion, which is easily repaired.

The writer has seen many falls of roof dislodge considerable lengths of cable, in some cases as much as 200 tubloads, but he has never seen a

severance of the main cable from this cause. As above remarked, all danger of a short circuit can be avoided by carrying one cable along each side of the road.

At each point where the branch-cables join the main circuit a double-pole switch should be inserted in the branch-line. This ensures that extensions of the various branches can be carried on without interruption to the current in the main circuit. At the face-end of each gate, along which the branch-cables are taken, double-pole switches should be placed: these fulfil the double purpose of forming a rapid means of connexion between the branch-cables and those which the machine drags after it along the face, and also of cutting off all current from the face when any work has to be done on the coal-cutter, a precaution which should always be observed.

This cable, which is dragged along the face, is obviously liable to very rough usage, and the writer has experimented with many kinds of cable in order to test their suitability. Twin and concentric cables are objectionable on account of their want of flexibility, liability to kink, and risk of short-circuit. Armouring the cable or serving it spirally with wire makes it less liable to abrasion, but a fall of roof or coal is almost certain to drive the armouring into contact with the copper core and thus put the circuit to earth. Here, again, the writer has found it by far the most satisfactory plan to use two lengths of ordinary vulcanized, strongly braided cable 40 yards long, *e.g.*, sufficient to carry the machine over 80 yards of face without disconnecting if the gates be 40 yards apart and every alternate one is wired. These cables, when abraded, can be patched and used in the gates for extension of the branch circuit. As an example of the economy of this plan the writer may mention that at a neighbouring colliery, where electric coal-cutters have been in constant operation for three years, and where from 3 to 4 miles of cable are in use, no cable has been discarded in that time or appears likely to be in the near future.

The writer will now state what he considers to be the essential features of a good electrical coal-cutting machine:—

1.—The electric motor should be of sufficient capacity to cope with any load likely to occur in the ordinary course of its work.

2.—The mechanical strength of the machine should be limited only by the consideration of size and weight.

3.—The rough usage to which the machine is subject renders it necessary that all electrical parts, which in themselves are comparatively fragile, should be efficiently enclosed and protected.

4.—The limited space available for the operator renders it of paramount importance that no precaution should be omitted to ensure safety of life and limb.

After a considerable experience of many types of electric coal-cutting machines, the writer is of opinion that the disc-wheel is by far the most suitable implement for long-wall coal-cutting. Its most persistent rival is the fast-running cutter bar; and it is claimed for the bar that it is lighter than the wheel, and allows the coal to be nogged much nearer to the cut than in the case of the wheel. The objection to the size and weight of the wheel can, as the writer has already shown, be avoided by having it split segmentally. The coal cut by the bar can certainly be nogged closer than in the case of the wheel, provided the holing-dirt has been dislodged from the cut. The wheel, owing to its large superficial area, has little or no tendency to climb, *i.e.*, to deviate from the plane of its cut, if the road-layer in front does his work properly. The bar-cutter, however, has an almost insuperable preference for the path of least resistance, a partiality which, in the writer's experience, often lands it high up in the coal: in fact, in the softest material it can find. Great care on the part of the workmen, and constant use of the adjusting-screws with which bar machines are usually equipped, may modify the tendency somewhat; but it is a vital fault, and greatly impairs the working capacity of the machine. The disc-wheel brings out its own holing-dirt, the bar does not; and if the holing be not raked out by hand at once any settling of the coal may pack the dirt so tight that it will be necessary to hole it again, an accident which often happens with a bar-cutter.

Again, if we compare the actions of the disc and bar-cutters it will be seen that the disc-wheel acts practically as a rip-saw and the bar as a crosscut saw; also, in the case of a broken cutter, the disc-wheel brings it out with the holing dirt, whilst the bar would have to cut through it, and as the cutters are made of the very toughest steel the effect on the bar is serious. From the above considerations one would not expect a bar to hole successfully in hard material—*e.g.*, hard bind with lumps or thick layers of iron pyrites, and in the writer's experience it has never satisfactorily done so.

Another class of coal-cutting machine makes use of a revolving chain, fitted with cutters, which do the underholing. The chief objections to the chain are its short life, owing to the great wear on its numerous moving parts and the great difficulty of lubricating it sufficiently. Mr. R. S. Williamson, of Cannock and Rugeley collieries, has used a chain cutter for some time in the bass coal-seam, but he is now installing disc-wheel coal-cutters.

The writer has dwelt at some length on this question of the form of implement best suited to effect the underholing, because it is obviously of great importance. He is strongly in favour of the disc-wheel, run at a speed of from 25 to 30 revolutions per minute, *i.e.*, at a speed considerably in excess of that used on air-driven machines; this is easily effected by using electricity, and by the increased speed the side thrust on the rails is greatly reduced.

The motor which drives the coal-cutter should be series-wound and capable of going up to 16 horse-power without undue heating. This last point is of great importance, for it must be remembered that the limit to the power of the machine is reached when the temperature of the windings reaches the safe working limit. It is nearly always advisable to have the armature of the motor thoroughly enclosed in an air-tight casing, and this, of course, whilst ensuring the windings against mechanical injury checks the natural dissipation of heat from the coils. The most suitable shape for the motor is either the Manchester or the ironclad. The writer prefers the latter shape on account of its compactness, its freedom from magnetic leakage, and the natural protection afforded to the field-magnet windings. The question of the voltage best suited for this work is one on which there may be considerable diversity of opinion. A low voltage would of course greatly increase the first cost and lower the efficiency of the plant; a pressure of 700 volts is frequently employed in mines for pumping and haulage-work with good results. In coal-cutting, however, where the cable erection at the coal-face is necessarily less permanent and where liability to leakage is greater, it will be found the better plan to use a pressure sufficient to give good efficiency, and yet too low to cause any injury through an accidental shock. A pressure on the surface of 400 to 440, giving, say, 380 volts at the motor, meets these conditions in a satisfactory manner.

The satisfactory working of the motor itself depends largely on the proper fixing and design of the brush-gear. In thin seams, where the space is confined, the brush-gear receives, as a rule, very little attention. In a brush-gear designed lately for this purpose, and now giving very satisfactory results, the brushes used are carbon, and the commutator-segments are cast copper.

It is of great importance in electrically-driven machinery that rigidity and absence of vibration should be secured as much as possible. If the rails on which the machine travels be not firmly propped and secured, the machine will not keep up properly to its work, and the current used will vary considerably instead of remaining steady. This irregularity of

working load can generally be remedied by careful attention to the form of rails and sleepers used. Suitable intermediate and joint steel sleepers have been designed for this purpose; they are light in proportion to their strength; they can be rapidly taken up and re-fixed; and as there is no necessity to detach any part, there is no possibility of any part being lost, a frequent occurrence when fish-plates and bolts are used. Rails weighing 20 lbs. to the yard have always proved strong enough for the purpose.

The efficiency of such a plant as that described above would be about 55 per cent.; from a corresponding compressed-air plant we ought to obtain an efficiency of 27 per cent. We can accordingly estimate the power of the air-compressing plant necessary to perform an equal amount of work. The approximate first cost of the two systems would be as follows:—

TABLE I.—COST OF ELECTRIC PLANT.

Two Lancashire boilers and seating	£800
Engine, 90 horse-power	380
Dynamo	340
Cables, 2 miles of 19/15 S.W.G., and 1 mile of 7/14 S.W.G.	440
Three electric coal-cutting machines	960
Switch-board, switches, etc.	50
Erection of plant	50
Total	£3,020

TABLE II.—COMPRESSED-AIR PLANT.

Three Lancashire boilers and seating	£1,200
Engines and air-compressors	700
1 mile of pipes 5 inches in diameter, and ½ mile of pipes 3 inches in diameter	500
Nuts, bolts, washers, joint-rings, etc.	30
Fixing pipes	75
Air-receivers, above and below-ground	100
Four air-driven coal-cutting machines	640
Total	£3,245

A comparison of Tables I. and II. shows a saving of £225 on first cost in favour of electricity.

The following figures show the approximate yearly working cost of the two systems:—

TABLE III.—COST OF WORKING ELECTRIC PLANT.

Charge, 15 per cent. on capital outlay	£450
Two enginemen at 30s. per week	150
Four stokers at 25s. per week	240
Stores and repairs	150
Fuel, 2,000 tons at 4s.	400
Extension of cables and fixing	180
Underground labour charge, 120,000 yards at 2d. ...	1,000
Total	£2,570

On a yearly output of 180,000 tons, the cost of machine-cutting will be 3·42d. per ton.

TABLE IV.—COST OF WORKING COMPRESSED-AIR PLANT.

Charge, 15 per cent. on capital outlay	£480
Two enginemen at 30s. per week	150
Six stokers at 25s. per week	360
Stores and repairs	200
Fuel, 4,000 tons at 4s.	800
Extension of pipes and fixing	300
Underground labour charge, 120,000 yards at 3d. ...	1,500
Total	£3,790

On a yearly output of 180,000 tons, the cost of machine-cutting will be 5·05d. per ton.

It will be seen from the preceding tables that the high efficiency of the electric-driven machine, coupled with the fact that it takes at least four air-driven machines to do the work of three electric-driven machines, enables electricity to show a very handsome annual saving over compressed air.

The writer has prepared Table V., giving the results obtained at a number of collieries during the last two or three years. The machine is driven in each case by two men whose wages aggregate 12s. per day. The figures relating to Nos. 6 to 8 collieries have yet to be verified, and are estimated on those attained elsewhere and on a very careful examination of the seam and the conditions obtaining at the coal-face.

The writer hopes to be able at a near date to lay further results before the members, and can only hope that the above remarks and results may have the effect of directing attention to this important branch of coal-mining, and stimulating discussion as to the readiest means of obtaining the best results. If that hope be realized, the writer will have the satisfaction of feeling that his humble endeavours have not been altogether in vain.

TABLE V.

Name of Colliery.	Depth of Undercut.	Nature of the Holing Material.	Average Length of Holings Cut per Day.	Sets of Cutters Used per Shift.	Thickness of Coal.	Labour Cost of Holing per Ton.	Average Electrical Horse-power at Dynamo per Machine.
	Feet.		Lin. Yds.		Feet.	d.	H.-P.
1. Lidgett	3½	Strong bind, with lumps of pyrites	55	4	2	3·30	21
2. Nostell	4½	Hard bind, with pyrites in thin layers	80	2	3	1·40	18
3. Astley and Tyldesley	3½	Strong spavin, without pyrites	75	2	3½	1·40	17
4. Stanton—							
* (*a*) Stanhope coal-seam ...	4½	Soft spavin	85	1	5	0·84	16
* (*b*) Eureka coal-seam ...	4½	Hard spavin	80	2	4	1·00	18
5. Sutton—							
(*a*) Top hard coal-seam	4½	Ordinary spavin	70	1	5½	0·90	17
(*b*) Dunsil coal-seam	4½	Hard spavin	75	2	3	1·30	18
6. Aber—							
No. 3 coal-seam ...	3½	Hard stone bind	80	2	3	1·60	17
7. Cannock and Rugeley Bass coal-seam ...	4½	Bind	80	1	5½	0·81	17
8. Blackwell—							
Deep hard coal-seam	4½	Spavin	80	1	3½	1·10	17

* In the case of those collieries marked with an asterisk, three men were employed with the machine, as the timber setting required considerable time and care.

Mr. T. B. A. CLARKE said that a machine was running at the Union Foundry, and invited the members to inspect it after the meeting.

Mr. THIRKELL moved that a vote of thanks be given to Mr. Clarke for his able paper.

Mr. A. A ATKINSON seconded the resolution, which was carried unanimously.

Dr. JOHN S. HALDANE read the following paper on "The Causes of Death in Colliery Explosions" :—

THE CAUSES OF DEATH IN COLLIERY EXPLOSIONS.

By JOHN S. HALDANE, M.A., M.D., Lecturer in Physiology, University of Oxford, and Grocers' Company Research Scholar.

On the occurrence of the explosion at Tylorstown colliery, in January of the present year, the writer was asked to investigate the actual causes of the deaths of those who had been killed in the explosion, and to draw up a report on the subject for the Home Office. While this report* was passing through the press, two other serious explosions occurred—at Brancepeth and Micklefield—and the writer went to both places in order to collect further information, and to give any possible assistance.

The report is now published, but a short additional paper on the subject, with some demonstrations, will, perhaps, be of interest to members, and serve as a starting-point for discussion as to whether the facts collected show that any further practical steps can be taken with a view to diminishing the loss of life in explosions.

The first and most salient point which came out in the investigation was that the actual cause of death was, in almost every case, poisoning by carbon monoxide. Facts pointing to the presence of carbon monoxide in after-damp have already been brought forward by several observers—particularly by Messrs. W. N. and J. B. Atkinson, in their book on *Explosions in Coal-mines*; but it came to the writer as an entire surprise that the presence of this gas after an explosion was nearly always the actual cause of death. It seemed probable that many men must be killed by absence of oxygen in the after-damp, and many others by burns or violence. Analyses of the blood showed that this was not the case. It would seem that the after-damp left along the track of an explosion is so largely diluted with fresh air that more than enough of oxygen is left to support life. Probably this is owing to so great an excess of dust being present during the explosion that in many parts of the mixture the temperature of ignition cannot be reached, or the flame is drowned out.

As regards the violence and the severity of the burns, the writer thinks that these are apt to be exaggerated. In every great explosion several of the bodies are much mutilated when discovered. The head or

* *The Causes of Death in Colliery Explosions and Underground Fires.*

limbs may be smashed or torn off, or there may be fractures, dislocations, or severe bruises. Sometimes, however, these injuries have undoubtedly been inflicted after death by the falls of stone which continue for many hours after an explosion, in consequence of the displacement of timbering. The burns are, as a rule, quite superficial. The bodies which have been burned are nearly always thickly encrusted with fine coal-dust, which has adhered to the skin, and the blackening thus produced is sometimes mistaken for charring. On rubbing off the coal-dust, however, it will be found that the deep skin is nearly always intact, although the epidermis is completely loosened over the backs of the hands. This is not due to blistering, but seems to occur almost instantaneously, and to be caused by the momentary application of intense heat, which gives rise to a sudden development of gas and aqueous vapour under the epidermis. Beneath the loosened epidermis of the backs of the hands the deep skin is normally quite white, moist, and intact. Men who have been got out suffering from these superficial burns of the face and hands constantly recover, if they do not die of the after-effects of carbon monoxide poisoning. Where, however, the body has not been protected by clothing, the chances of recovery must be slight.

The practical point to ascertain, however, is not so much the actual cause of death as the proportion that might conceivably be saved, if suitable means of rescue could only be devised to save them from the after-damp. A rough estimate on this point will, the writer thinks, be of service, although there must of course be a good deal of uncertainty in judging of the danger to life from the burns.

Of the bodies examined at Tylorstown, only 31·6 per cent. were not burnt. Of those burnt or injured nearly half would, the writer believes, have ultimately died apart from the effects of after-damp. Hence about 66 per cent. might have been saved, but for the after-damp.

At Micklefield 67 per cent., and at Brancepeth 60 per cent. were neither burnt nor injured. At Micklefield 76 per cent., and at Brancepeth 90 per cent. would probably have escaped with their lives, but for the after-damp. Thus, taking the average of these three explosions, we may say that about 77 per cent. might have escaped, but for the after-damp.

This is hardly the place for entering minutely into medical details, but a short account and demonstration of the means of chemically recognizing carbon monoxide both in the air and in the bodies of those killed may interest members of the Institution.

Carbon monoxide (CO), or carbonic oxide, is a compound of one atom of carbon with one atom of oxygen. It is found, along with carbon dioxide (CO_2), or carbonic acid gas, wherever combustion occurs in the presence of an amount of oxygen insufficient to consume the whole of the carbon and hydrogen which are actually undergoing combustion. Where sufficient oxygen is present only carbon dioxide is formed. Now, carbon monoxide possesses one property (discovered by Prof. Claude Bernard) which renders it a deadly poison to all warm-blooded animals. It enters into a very firm combination with the hæmoglobin, or colouring-matter, of the red blood-corpuscles. Under normal circumstances the hæmoglobin combines loosely with oxygen in the lungs, and carries this oxygen to the tissues. The compound of carbon monoxide and hæmoglobin is, however, incapable of combining with oxygen. Hence, after the blood has absorbed a sufficiency of carbon monoxide, it becomes incapable of carrying enough oxygen to the tissues to support life, and death from want of oxygen ensues. The symptoms of carbon monoxide-poisoning are, as the author has recently shown,* absolutely the same as those produced in other ways by deficiency of oxygen; and if one can by indirect means supply the tissues with a sufficiency of oxygen, carbon monoxide loses its poisonous properties.

The writer showed a jar containing about 80 per cent. of carbon monoxide and 20 per cent. of oxygen. The members saw that the cockroaches placed in this jar continued to live quite comfortably. They have no hæmoglobin in their blood, and consequently they are indifferent to this mixture, which would at once kill a higher animal. The other jar contained about 80 per cent. of carbonic acid, and 20 per cent. of oxygen, and rendered a cockroach motionless within a few seconds, so that these animals are in realilty exceedingly sensitive to the action of poisonous gases.

The compound of carbon monoxide with hæmoglobin possesses a bright red colour, exactly like that of arterial blood saturated with oxygen or air. Three vessels were shown to the members containing respectively bloo saturated with oxygen (bright scarlet), blood deprived of oxygen (da purplish blue), and blood saturated with carbon monoxide (bright scarlet Death from carbon monoxide poisoning may be recognized from the f that the colour of the blood after death is more or less red instead of bl The bodies thus often present an extraordinarily lifelike appearance. T lips and tongue are pink, and the skin has a lifelike reddish colo Sometimes, however, the lips and skin are so pale that it is difficult t

* *Journal of Physiology*, 1895, vol. xviii., pages 200 and 430.

recognize the pink colour. When the blood is largely diluted with water the presence of carbon monoxide can be recognized with the greatest ease from the colour of the solution. When sufficiently diluted, blood containing carbon monoxide has a pink colour, while normal blood is yellow. This simple colour test is by far the most delicate one.

Three narrow test tubes were shown containing blood diluted to 0·01 with water. One contained normal blood, the next contained blood fully saturated with coal-gas (which contains carbon monoxide), and the third contained blood from the body of a miner who was killed by carbon monoxide poisoning. The members could see at a glance that the miner's blood is about 80 per cent. saturated with carbon monoxide; and this latter saturation is the maximum consistent with life.

For the chemical recognition of carbon monoxide in air blood-solution is by far the most convenient reagent. All that is necessary is to shake up a sample of the suspected air for a few minutes with about 0·05 of its volume of dilute blood-solution, and then to compare the tint with that of part of the same solution which has not been so shaken up. For details as to the quantitative application of this test, the writer must refer to a paper which he recently published.* A bottle and tubes were shown fitted up for conveniently carrying out the test. Bright daylight affects the reaction, so that the shaking should be carried out in the dark, or the bottle covered with a cloth. Unfortunately this test would not be satisfactory in a mine, as one cannot see the tints distinctly by artificial light, and it would therefore be necessary to bring the bottle to the surface.

For rapidly detecting poisonous proportions of carbon monoxide the best indicator is a small warm-blooded animal, such as a mouse. The mouse is not more sensitive to carbon monoxide than a man, but it shows the symptoms of poisoning in about the twentieth of the time. Hence a rescuer carrying a mouse with him will receive ample warning of the presence of after-damp or of carbon monoxide in dangerous proportions. It should be understood that this test cannot be relied on to do more than indicate the presence of actually dangerous proportions of carbon monoxide, for only a practised observer could detect the outward signs of slight symptoms in a mouse, whereas correspondingly slight symptoms in a man might be very distinctly felt by the subject of them. If the mouse merely shows signs of weakness of the legs there will be danger to a man, though probably not for twenty minutes or half-an-hour. If the mouse becomes quite helpless and unable to stand there is danger within a few minutes to a man. If the mouse

* *Ibid.*, page 463.

becomes unconscious and goes into convulsions there is urgent danger, and not a moment should be lost before retreating.

An apparatus was shown for demonstrating on man, and on a mouse the facts just referred to.

The first symptom of carbon monoxide poisoning is an unusual tendency to dizziness, palpitation, and shortness of breath on exertion; along with this there may be drowsiness. As more and more of the poison is absorbed the power over the limbs becomes less and less, so that finally any exertion causes the legs to give way, and it is hardly possible for a man to make his escape. Finally, consciousness is gradually lost. There is no pain, and little or no mental distress, the action being almost like that of a gentle anæsthetic. The first distinct symptoms occur when the blood is about 30 per cent. saturated. At about 50 per cent. saturation the power of walking is lost; and death occurs at about 80 per cent. saturation. With about 0·06 per cent. of carbon monoxide in the air the blood of a man becomes about 30 per cent. saturated after 1½ hours, so that the symptoms become appreciable when any exertion is made; 0·10 per cent. would cause helplessness after about an hour; with more than 0·20 per cent. life would be endangered.

When a man who has absorbed much carbon monoxide reaches cooler and fresher air again he very often gets much worse, and may lose consciousness. What the explanation of this is the writer does not know, but there is no doubt about the fact. Men who are brought out, or who are just able to walk out, of air containing after-damp should be carefully covered up, and not allowed for some time to make any exertion. The writer is inclined to think that neglect of this precaution may even lead to loss of life.

A man who has been rendered unconscious from carbon monoxide poisoning suffers severely from the after-effects. If the exposure has been long he may die a considerable time after the blood has quite freed itself from the poison. With a shorter exposure he may remain unconscious for many hours, and only very gradually recover. Slighter poisoning without loss of consciousness is followed by very severe headache, and nausea during recovery.

The best remedy in carbon monoxide poisoning is the administration of pure oxygen. This rapidly drives out the carbon monoxide from the blood, although it is of no avail against the after-symptoms. Artificial respiration should be at once applied if the breathing ceases, or is very shallow. If the pulse be weak, stimulants should be given.

A bottle was shown filled with a mixture of pure oxygen with 0·50 per cent. of carbon monoxide. This proportion in air is rapidly poisonous to a mouse, but in presence of the oxygen the animal placed in the bottle remained unaffected.

It seems now to be thoroughly well established, thanks to the work of Mr. H. Hall, Mr. W. Galloway, Messrs. W. N. and J. B. Atkinson, and many others, that in all great colliery explosions the flame is propagated through the workings by dust, and practically speaking by dust alone. The flame extends from the point of origin—a shot or a small gas explosion—along the dusty (intake) haulage-roads in every direction, and usually passes up the downcast shaft. The return-airways (unless they are used for haulage) are unaffected. Some of the main intake-roads may be spared, and the flame may not reach the working-face at any point, but often it does so. Air-crossings, timberings, and doors along the haulage-roads are blown out; and in consequence of this the air-current through the mine is arrested. Often, too, the timbering connected with the fan-drift is blown out, and cannot be repaired for an hour or more. Thus, roughly speaking, the main intake-roads are left charged with stagnant after-damp, besides being more or less obstructed by falls, and dangerous on account of the state of the roof. The return-airways, except when they are close to the (intake) haulage-roads, or are themselves used for haulage, will be at first free from after-damp, besides being free of falls, and for a man who knows the way they will in some cases present a clear way of escape to one or both shafts. In many parts of the mine the air at the face, where the flame has not penetrated, will also be perfectly free of after-damp, and may remain so for hours, or even days. Nevertheless one finds again and again that men who would have been in perfect safety had they remained where they were, have from want of knowledge, tried to force their way along the intake-airways to the shaft, and consequently perished in the after-damp. The bodies are generally found in groups along the intake-airways, at points a little beyond where the men have met the after-damp. Horses and ponies which they have left behind are sometimes found quite uninjured.

What, now, is the composition of the mixture of gases filling the roads traversed by an explosion? In the first place, there is plenty of oxygen left along these roads. Out of about 120 bodies examined after the three explosions referred to, not one presented the appearances of death from want of oxygen. Timbering, etc., which has been on fire

after the explosion, is also very commonly met with, and, of course, this burning could not occur except in presence of a very large proportion of fresh air. At Micklefield, a quantity of paraffin close to the downcast shaft caught fire, and, according to the evidence of a survivor, was burning fiercely as he made his way out of a room in which he had been sitting, as the blast passed towards the shaft, and knocked him over. Now, a paraffin flame is ordinarily extinguished when the oxygen percentage falls below about 17 per cent., though it would probably burn with a somewhat lower percentage in the heated air. It would thus seem that the after-damp is from the beginning very largely diluted with air. At Micklefield and Tylorstown, none of the explorers met with after-damp which would extinguish a lamp, and a lamp goes out when the oxygen percentage falls from 20·9 to 17·5 per cent. The writer is inclined to think that perhaps two-thirds of the mixture left along the roads is, on an average, pure air, the remainder being after-damp.

About a year ago the writer assisted at some experiments which were very kindly made for him, at the suggestion of Mr. Wardell, H.M Inspector of Mines, by Mr. C. E. Rhodes, of Aldwarke Main colliery. The shell of a large boiler was used as an explosion-chamber, and dust kindly sent from the Albion colliery was employed in the experiments. There was no difficulty in producing violent explosions inside the boiler, but pure after-damp could not be obtained for analysis, or indeed any gas which would extinguish a lamp, or produce physiological symptoms. This failure caused some surprize at the time, but the writer thinks that the explanation was that, just as was subsequently inferred to be the case in actual pit explosions, only a portion of the air within the boiler was actually consumed, and the aspirating tubes never happened to reach this portion.

Assuming, then, that the pure after-damp along the track of an explosion constitutes only about half or a third of the mixture of gases present, and that there is plenty of oxygen left to support life, what is the proportion of carbon monoxide present? From the analyses of blood from the bodies found along the course of the explosion at Tylorstown, the writer thinks it may be pretty safely concluded that there was less than 3 per cent., and more than 0·50 per cent. The reasons for this conclusion will be found in the writer's *Report*. About 1 or 1½ per cent. would probably be a fair estimate. If this were so, the pure undiluted after-damp would contain 3 or 4 per cent. of carbon monoxide.

Probably the actual percentage varies somewhat with different kinds of coal-dust, and in different parts of the pit. Thus it seemed to the

writer that at Micklefield, the appearances of the bodies and the symptoms experienced by the rescuers pointed to a somewhat higher average percentage of carbon monoxide in the air than at Tylorstown. When there is more than about 2 per cent. of carbon monoxide, death occurs before the blood of the veins has time to become 80 per cent. saturated with the gas. In such cases, the face and neck have a reddish-blue appearance, instead of being pink. At Tylorstown, these signs were only noticed in two of the bodies (not burnt), which we afterwards found had been discovered lying close to one another in a stable. At Micklefield, on the other hand, seven out of forty-six of the bodies had this appearance. None of these bodies were burnt, and it thus seemed as if the higher proportions of carbon monoxide had been produced at places where the combustion was relatively gentle, and beyond, or sheltered from, the main rush of burning dust and air.

The writer must now pass from the more purely medical aspects of the causes of death in explosions, and make some suggestions as to what measures seem possible for avoiding or getting rid of afterdamp. He knows that in dealing with this very difficult subject he is handicapped by his want of knowledge of mining engineering, but he thinks that those who possess the requisite engineering knowledge are often nearly as much handicapped by want of knowledge of the medical side of the subject, and that a fellow-feeling will thus induce them to deal leniently with any mistakes which he may fall into.

The first remarks which he has to make concern the steps which should be taken by the men imprisoned in the mine, at the face or beyond the actual track of the explosion. Very often their lamps are extinguished by the rush of air and coal-dust driven towards them along the roads, and, in any case, their natural impulse seems to be to make at once for the shaft along the ordinary intake haulage-roads. The plans contained in the *Reports* of H.M. Inspectors of Mines tell a terrible story of the consequences of this. The men soon meet the after-damp on the roads, and drop. Their bodies are found scattered or in groups along the roads. Where a fall has already come down, a number of bodies are often found just beyond. Those who know what a haulage-road traversed by an explosion is like, will realize how slight the chances are for men—either with or without lights—of ever reaching the shaft. The best plan for those imprisoned would seem to be to remain in the first place where they are, and, if possible, to erect curtains or stoppings of some kind between themselves and the main roads, in order to keep back the after-

damp. The curtains should be erected at a point beyond a door opened towards a return-airway, so that the after-damp, carried inwards as the rescuers restore the ventilation, may have a free passage into the return-airways, and not be driven in upon the men. Any attempt to get out should be made with the utmost caution, and whenever after-damp is encountered the only safe plan is to retire. In attempts to get out one man only should go on slowly in front, two or three men some distance behind, being ready to rush in and drag him back should he fall. The reason for this precaution is that carbon monoxide only accumulates slowly in the blood, and a man who is fresh can generally go with perfect safety for a short time for rescue purposes into an atmosphere which would after a while produce deadly effects. It will often be much easier to reach the shaft by return-airways than by the haulage-roads, and one way may be tried if the other proves impracticable; but whichever way is taken, the utmost caution is necessary, on account of the very insidious action of the after-damp. When all ways of escape are for the time blocked, every effort should be made to keep back the after-damp by curtains or stoppings until the rescuers make their way in. Imprisonment for several days without food or drink is not dangerous, although far from pleasant. In many mines fire-damp will accumulate near the higher parts, and make a prolonged stay at the face impossible; but the fire-damp will drive back the after-damp; and it must also be remembered that it requires about 60 or 70 per cent. of fire-damp to endanger life, although $5\frac{1}{2}$ per cent. will put out a lamp.

In many cases where the flame reaches, or nearly reaches, the face, the only possible chance of escape would seem to be by the return-airways, if these can be reached in time. It is provided by law that there shall always be two ways of escape from a mine. This provision would seem, however, to be in some emergencies useless, through the men not knowing the way by the return-airways, and having no fireman, or other officer of the pit to guide them at the time. If the author be right as to this, the matter certainly seems to deserve attention. In the case particularly of an underground fire in an intake-airway a man's only chance may be to hurry out along a return airway.

The first thing which is thought of by those on the surface is, of course, the getting of air into the pit. The writer believes that if the fan has been damaged or thrown out of action by injuries at the top of the upcast shaft, fresh air will at first pass down the upcast shaft freely, in consequence of the suction produced by the heating of the sides and contained air in the downcast shaft, up which the flame has probably passed. This,

at least, was the case at Micklefield, where the first of the rescuers descended by the upcast shaft, brought out a number of men alive, and even penetrated a considerable distance inwards, although the fan could not be got ready for about twelve hours. The work of temporarily restoring the stoppings, doors, etc., and so carrying the air inwards, would be much facilitated by using mice as indicators of the presence of after-damp. Without some such indicator not only are the dangers to the rescuers very great, but much time must be consumed in helping disabled comrades, or from uncertainty as to where the after-damp is.

The writer also feels confident that in many explosions the provision of some simple apparatus for penetrating irrespirable atmospheres would also be of much service. The apparatus need only be used where it is desirable for a rescuer to go temporarily into a dangerous atmosphere. The main thing would always be to carry the fresh air inwards with the rescuers. Men employing any apparatus would have to be instructed beforehand in its use. An atmosphere containing carbon monoxide is not the place for trying hasty experiments. For the revival of disabled men, whether or not they have been burnt and injured as well as poisoned, the writer thinks that oxygen cylinders would be of great service. Although in severe cases it will not restore consciousness, the oxygen will in a few minutes drive out most of the carbon monoxide from the blood, and thus give a man the best chance of coming round.

It seems to the writer that considering the risks of an explosion in any fairly dry pit, however free from fire-damp, arrangements should be made beforehand for minimizing, as far as possible, the loss of life should an explosion occur. In the first place, he feels certain that means might be devised for shortening the time which usually elapses before fresh air is again circulating through, at least, the main roads after an explosion. From an examination of the bodies found along main roads he feels confident that, although consciousness must very soon be lost, an interval of half-an-hour to an hour or more commonly elapses before death occurs from carbon monoxide poisoning, and that any plan for getting in fresh air within this time may be the means of saving many lives. As things are at present, there is nearly always a fatal delay. Very often the timbering connecting the fan with the fan-drift is blown out, or the covering of the upcast shaft is blown off, and this causes much delay and great danger to rescuers. This might, perhaps, be avoided by the provision of light movable flaps, which by opening outwards would relieve the pressure caused by the rush of air up the upcast shaft.

Further delay arises from the blowing out of doors, stoppings, and air-crossings connecting the main intake-airways with the main return-airways. These main air-crossings, etc., might surely be so solidly constructed as not to give way. The pressure during an explosion is probably not nearly so formidable as is sometimes assumed. So far as the writer is aware there is nothing in a colliery explosion remotely resembling the detonation of, say, a mixture of hydrogen or fire-damp with pure oxygen, and the greater part of the energy liberated by the combustion must be rapidly taken up by the large excess of coal-dust swept up by the blast.

If the means suggested were successful, the writer believes that men lying along the main roads would (with the exception of the very few who are killed at once by violence) have a chance of recovery, and that those further in would have a much better chance of escape. It does not seem desirable, even if it were practicable, that anything but the doors, etc., on the main roads should be so made as to resist the pressure; otherwise, the after-damp would be carried inwards towards the face, instead of straight into the return-airways by the first blown-out door or air-crossing. A simple calculation will show that the fan is capable of clearing the shafts, and a mile or more of the main roads, within a very few minutes. If the fresh air be got in at once it will probably encounter very little obstruction from falls, which seem mostly to come down gradually.

For men far in, all the means suggested would, the writer fears, avail little in cases where the flame reaches up to, or close to, the face. Escape will often be cut off in every direction, and the after-damp will very rapidly close in. This is what happened, for instance, with the great majority of those who were killed in the Llanerch explosion. They had only gone a short way before they were overcome; and even had they stayed in their places they would probably also have perished. To meet such cases it seems to the writer that probably the least expensive and most practicable method would be to provide within easy reach some form of oxygen apparatus for enabling the men to make their way out to the fresh air near the shaft, and to have them previously instructed in the use of this apparatus. The writer does not think that there can be any doubt as to the practicability of this plan, but the trouble and expense would be considerable, in view of the fact that in most pits a serious explosion never occurs at all. Now that we know that there is plenty of oxygen left along the track of an explosion, the writer believes that the whole problem would be solved if only a cheap and

efficient absorbent could be found for carbon monoxide. Air can be freed by means of respirators from almost any other poisonous gas, and it is singularly unfortunate that the blood passing through the lungs should be just the one thing which absorbs carbon monoxide rapidly.

The prevention of colliery explosions does not, of course, come within the scope of this paper, but the writer can hardly refrain from adding his voice to that of others who have already urged the pressing need of careful experiments with a view to determining the available means of preventing the propagation of explosions by coal-dust. Each new explosion is, of course, a new experiment; but it is a terribly costly one, and often the facts connected with it either cannot be ascertained, or, if ascertained, afford no new information.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, Staffordshire) congratulated Dr. Haldane on the great amount of pains and trouble that he had taken in investigating the subject of the cause of death in colliery explosions. All persons interested in the safety of mining and the rescue of life would feel a great debt to Dr. Haldane for his investigations. Perhaps the immediate practical results might not be very great, but none could tell the results which might follow from the discovery of the causes and methods of action both with regard to the explosions themselves and the effect on human life. One very useful piece of information was with reference to the use of pure oxygen for the purpose of recovering men from the effects of after-damp. He had attended at many explosions, but at none of them was any use made of compressed oxygen. It would not be easy to obtain in every case, but there were many places where it was stored in iron bottles, and it might be made use of without difficulty. Another point deserving of consideration in respect of explosions was that there were several kinds of apparatus which might be useful in explosions and fires, such as masks or appliances for going into after-damp and gases, and electric lamps for use in such cases; it would not be reasonably possible for each colliery to keep a supply of such articles, but it would be useful if in some central place in a mining district they could be kept in the care of people competent to use them, so that whenever an accident took place there might be not only apparatus ready, but men competent to use it.

Mr. JOHN GERRARD (H.M. Inspector of Mines, Manchester) seconded all that Mr. Atkinson had said with regard to their indebtedness to Dr. Haldane for the very great pains and time which he must have given to this subject. He was enlisted in a noble cause, that of leading mining engineers in such an important question affecting, as it must affect, life. The members knew the anxiety experienced by those who had charge and responsibility, if there were anyone in the mine who might be brought out alive.

He (Mr. Gerrard) did not reject the idea of one of the explorers carrying a live mouse with him. Usually several men went in company, walking in single file. All would have lamps, but as Dr. Haldane had shown, and as had been proved in the past, the lamp continued to burn and did not show the poisonous nature of the gases traversed by the explorers. Dr. Haldane had shown how important it was to pay attention to the first symptoms affecting the head, of giddiness, or weakness of the legs, and to at once retreat, as the same atmosphere which had brought about the symptoms had again to be travelled through. The desire to save life in the past had been so intense that men had advanced until they could go no further, and then they had had to return through the same atmosphere. All men did not feel alike. On more than one occasion he had felt all right when another man had been in a helpless state, and had to be carried out. Could Dr. Haldane hold out any hope of a medium being discovered which would absorb the carbon monoxide, and could be used in the form of a respirator.

The PRESIDENT moved a vote of thanks to Dr. Haldane for his paper and the experiments. Many of the members had had underground experience after explosions. He hoped that Dr. Haldane's suggestion would be carried out, and that a respirator might be devised which would perhaps prevent or at least diminish the worst of the symptoms.

The vote was carried by acclamation.

The annual dinner was held in the evening at the Queen's Hotel.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING OF THE WESTERN AUSTRALIAN BRANCH,

HELD AT THE VICTORIA HOTEL, COOLGARDIE, JULY 6TH, 1896.

MR. G. GRAVES GIFFORD IN THE CHAIR.

Mr. EDWARD HALSE was asked to act as Honorary Secretary for the present, and expressed his willingness to do so.

The following resolutions were carried unanimously:—

(1) That the correspondence from the Secretary (Mr. M. Walton Brown) be acknowledged, and that the members present at the meeting, as well as some of those absent (their letters having been read), consider it advisable to adopt the views of the Council of the Institute, as expressed in the circular letter dated March 2nd, 1896.

(2) That a General Meeting be called at an early date for the purpose of appointing officers and transacting other business, the date of such meeting to be left in the hands of the Chairman and the Honorary Secretary.

(3) That the members present constitute a committee to assist the Honorary Secretary.

(4) That the members resident in Western Australia be asked to contribute £1 1s. each towards the current expenses in connexion with the formation of the proposed Branch.

(5) That the Chairman and Honorary Secretary draw up a list of subjects for discussion, to be presented at the next meeting for the consideration of the members.

(6) That the Honorary Secretary be authorised to write to the Secretary (Mr. M. Walton Brown), asking the Council to furnish the members in Western Australia with rules for their guidance in forming a Branch or other body of the Institute.

The meeting then terminated.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING OF THE WESTERN AUSTRALIAN BRANCH, HELD AT 398, SHAW STREET, COOLGARDIE, JULY 13TH, 1896.

MR. H. P. WOODWARD, F.G.S., IN THE CHAIR.

The minutes of the last meeting were read and confirmed.

The following resolutions were passed unanimously:—

(1) That a Branch of The North of England Institute of Mining and Mechanical Engineers be inaugurated in Western Australia, and be called the "Western Australian Branch."

(2) That the following officers constitute the governing body of this Branch of the Institute, namely, Chairman, three Vice-Chairmen, Honorary Secretary and Treasurer, together with a Committee of seven in addition to the above, who are *ex-officio* members thereof.

(3) That Mr. H. P. Woodward be appointed the Chairman of the Western Australian Branch.

(4) That Messrs. F. H. Backhouse, Uriah Dudley, and G. Graves Gifford be appointed Vice-Chairmen of the Branch.

(5) That Mr. Edward Halse be appointed Honorary Secretary and Treasurer.

(6) That the following Members and Associate Members constitute the Committee:—Messrs. J. W. Archibald, E. T. Bailey, C. Chewings, E. D. Cleland, F. G. de V. Gipps, G. Graves Gifford, and F. Bowes-Scott.

(7) That at an early date a Committee meeting be held to recommend candidates for election by the Institute, and that the members of the Committee be requested, if unable to attend the meeting personally, to send in lists of names of persons they would propose, together with their qualifications.

The meeting then closed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE MINING SCHOOL, WIGAN, JULY 14TH, 1896.

MR. THOMAS DOUGLAS, PRESIDENT, IN THE CHAIR.

The MAYOR OF WIGAN (Alderman Layland) said that the inhabitants of the borough, as well as those who were engaged in mining and mechanical operations in the important surrounding districts, were pleased that the Institute had fixed upon Wigan as the place for their excursion meeting this year. The industries of the district were largely dependent on coal, cotton, and iron, and these in turn were dependent for their success on the knowledge by which they were produced, stored, and turned to good account by means of institutions like The North of England Institute of Mining and Mechanical Engineers. He found from the list of members for election that they were drawn from Western Australia, British Columbia, Colorado, Transvaal, Newfoundland, etc., and it was very evident that the benefits of The North of England Institute of Mining and Mechanical Engineers were worldwide, and the success and usefulness of its operations were universally felt. He had great pleasure in giving the members a hearty welcome.

The PRESIDENT thanked the Mayor of Wigan for interesting himself in their meeting. He knew that the people of the Wigan district took very great interest in mining and scientific subjects. That to him was an extremely gratifying matter, and he had no doubt—gathered together, as they were to assist one another so far as they could with information and knowledge—that their visit to Wigan would be very pleasant and profitable to each of them. The President then proposed a vote of thanks to the Mayor of Wigan for being present and giving them his address of welcome that day.

The vote of thanks having been cordially adopted, the Mayor briefly acknowledged the compliment.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meeting that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. EDMOND C. VAN DIEST, Manager, The United States Freehold Land and Emigration Company, San Luis, Colorado, U.S.A.

Mr. HENRY EDWARD EDE, Mining Engineer, The Rectory, Gateshead-upon-Tyne.

Mr. FREDERICK WILLIAM GREY, Mining Engineer, Dashwood House, 9, New Broad Street, London, E.C.

Mr. JAMES GUNSON LAWN, Professor of Mining, Royal College of Science, South Kensington.

Mr. JOHN LIDDELL, Assistant Engineer, De Beers Consolidated Mines, Limited, Kimberley, South Africa.

Mr. CLAUDE VAUTIN, Metallurgical Chemist, Bevois House, 28, Basinghall Street, London, E.C.

Mr. JOHN WATSON, Analytical and Metallurgical Chemist, 28, Levaine Place, Newcastle-upon-Tyne.

Mr. SAMUEL HERBERT WILLIAMS, Mining Engineer, c/o Anglo-American Exploration Company of Western Australia, Limited, Coolgardie, Western Australia.

ASSOCIATE MEMBERS—

Mr. A. J. COLQUHOUN, School of Mines, Vancouver, British Columbia.

Mr. JOHN MACINTOSH DONALD, The Bantjes Consolidated Mines Limited, P.O., Florida, Transvaal.

Mr. C. A. FERGUSON, Mining Student, 36, Eldon Street, Newcastle-upon-Tyne.

Mr. GILLMORE GOODLAND, Ravenswood, Queensland, Australia.

Mr. FRANCIS G. HARVEY, Plus Le Désir, Canal No. 1, Demerara, British Guiana.

Mr. G. H. MARTIN, 189, Ashmore Road, Paddington, London, W.

Mr. G. F. MONCKTON, School of Mines, Vancouver, British Columbia.

Mr. JOHN WEBSTER, 83, Lombard Street, London, E.C.,

Mr. ARTHUR NICHOLAS LINDSAY WOOD, Engineer, The Hermitage, Chester-le-Street.

ASSOCIATES—

Mr. GEORGE DAYKIN, Deputy Overman, 24, Black Boy, *via* Bishop Auckland.

Mr. MILES PRATT, Overman, 33, Black Boy, *via* Bishop Auckland.

The SECRETARY read a paper by Dr. Haldane on "The Causes of Death in Colliery Explosions." *

* *Trans. Fed. Inst.*, vol. xi., page 502.

DISCUSSION ON DR. J. S. HALDANE'S PAPER ON "THE CAUSES OF DEATH IN COLLIERY EXPLOSIONS."*

Mr. J. GERRARD (H.M. Inspector of Mines, Manchester) said that the members must be glad to receive such very efficient assistance as was given in that able and valuable paper, following as it did upon Dr. Haldane's previous papers in connexion with carbonic acid gas. After-damp had been for a long time recognized as playing an important part in the loss of life from explosions. It had been over and over again said that three-fourths of the lives lost in explosions were due to after-damp, and it was very satisfactory to have it proved by Dr. Haldane.

Without going so far as to second Dr. Haldane's suggestion with regard to mice, he thought they could well adopt his suggestion with regard to the first symptoms, whether it was in the head or in the legs, and unquestionably to adopt his suggestions with regard to a timely retreat. One had seen men who had succumbed from perseveringly advancing, and forgetting that the atmosphere which had brought about the symptoms of danger had to be returned through. Dr. Haldane strongly advocated the speedy introduction of fresh air, but he did not think Professor Haldane anywhere noted one point which must be taken into consideration—namely, the danger of fire. Those who had been exploring after an explosion in a mine, and in the innermost recesses of the mine had discovered a fire in close proximity to fire-damp, knew the anxiety attending it; and whilst on the one hand every effort should properly be made to rescue anyone who might be living by taking in fresh air, yet, on the other hand, should a small smouldering fire be fanned into active flame by the too hasty introduction of air, it would create a danger greater, perhaps, than that warranted by the hope of rescuing a few persons who might be living.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, Newcastle-under-Lyme) wrote that Dr. Haldane's paper formed a valuable and instructive addition to our knowledge of the conditions leading to death in mines after an explosion. It was, he believed, the first time that a thorough and scientific study of the subject had been made from a medical point of view. To appreciate properly the study and labour which Dr. Haldane had devoted to the question it was necessary to read, in addition to this paper, his official report to the Secretary of State on *The Causes of Death in Colliery Explosions and Underground Fires.* There was no doubt that Dr. Haldane was right in the conclusion that in colliery explosions

* *Trans. Fed. Inst.*, vol. xi., page 502.

the actual cause of death was in most cases due to the after-damp, and the proof set forth that the most injurious component of after-damp in a dusty coal-mine was carbonic oxide accords with the observations of explorers in a number of explosions.

He agreed with Dr. Haldane that exaggerated statements had been made as to the severity of the burning effects in explosions; one heard of bodies being "charred to a cinder" and "roasted," but so far as his observation had gone he had seen nothing of the kind, and he did not believe that it occurred—except in rare cases where a man's clothing might be set on fire, and continue to burn after the explosion. The injury produced by burning depended chiefly on the amount of body-surface exposed, and a man completely clothed was not likely to succumb to the burning alone.

With reference to violence, in some cases the injurious effects on men could hardly be exaggerated, as for instance when a man was actually decapitated or his limbs torn off, but such cases of extreme violence only occurred to persons caught and hurled by the full blast, and they were comparatively rare. He agreed with Dr. Haldane, however, that nothing approaching the shattering violence of the detonation of a mixture of hydrogen or fire-damp and oxygen occurred in dust-explosions.

It was true that injuries were sometimes caused after death by falls of roof, but these cases were not common, because as a rule the falls took place at the moment of the explosion, and such falls as afterwards occurred were usually at places where there had been a previous fall at the time of the explosion. It was easy to distinguish falls which occurred after a dust explosion from those coming down at the time; in the former case, the surfaces of fracture exhibited their natural colour, whilst in the latter case, they were black, and coated with a velvety deposit of coal-dust.

Dr. Haldane's conclusion that sufficient oxygen remained in pure after-damp to support life for so long as ½ hour or 1 hour was extremely interesting, but before unreservedly accepting it, we required to be sure that oxygen, undoubtedly present at some points immediately after the passage of the blast of an explosion, might not have come in from adjacent passages not traversed by the explosion. Fires were frequently caused by explosions, and found burning by the explorers, in which cases it was evident that a supply of oxygen was available immediately after the explosion. No doubt there was always a great excess of coal-dust beyond the amount theoretically necessary from a chemical point of view to carry on an explosion, and only a comparatively small amount of the volatile combustible matter was expelled from the dust, but this appeared to be an

argument in favour of the complete exhaustion of the oxygen, and when we considered the great pressure which must exist during the progress of a mine explosion it appeared surprising if the flame did not actually fill the passage. On the other hand, in a boiler-flue fired with powdered dust, and as ordinarily observed through a sight-hole, at a fierce orange heat, an excess of dust would cause it to appear quite black and dark. The subject was one deserving further investigation, and this could only be done experimentally, because it was not possible to secure pure after-damp in a mine. From the point of view of saving life the source of the oxygen was not material, and apart from men in the actual track of an explosion, there was usually a much greater number who might be rescued if they refrained from rushing into the after-damp, and the explorers could reach them without forcing the after-damp on to them.

It was most desirable that the conditions leading to and brought about by extensive coal-dust explosions should be better known to miners, so that they might be able to take the best measures to save their lives; but beyond the general advice that it was almost certain death to attempt to pass through any considerable amount of after-damp, and that it was safer to retreat and take means to divert the after-damp, it was somewhat difficult to give specific instructions, because the construction of mines and the state of different roads with reference to coal-dust and liability to invasion by after-damp, differed so widely. It was therefore most desirable that a considerable proportion of the miners should be made acquainted with the return-airways by travelling through them periodically.

Fuller information was required as to the amount and degree of purity of coal-dust necessary to enable it to propagate an explosion, for although it was possible to predict of certain roads that a dust-explosion would or would not pass along them, there were other roads where our knowledge was insufficient to enable a judgment to be formed with any certainty; and the same uncertainty existed with reference to the length of the interval free from coal-dust which was necessary to arrest the advance of a dust-explosion. Experimental research on these points would be very useful.

Mr. J. L. Hedley (H.M. Inspector of Mines, Newcastle-upon-Tyne) said that Dr. Haldane had evidently studied the matter thoroughly, and what he had told them he had doubtless told them with very good warrant, but there were certainly several points to which he thought attention should be drawn. He gathered from the paper that Dr. Haldane thought the return-airway was the safer way to come out, but it depended entirely on the condition in which the mine was found after

the explosion. Men, after an explosion, naturally tried to take the quickest way out that they could; they went by the intake road because that was the road which they knew best. However, it was a well-known fact that the suggestion made by Mr. Atkinson had been already carried out in some of the mines in this county. It was all very well, however, for the members to suggest what a man should do when he was in a pit after an explosion; but they must remember that the men had not even got their lights to guide them. Dr. Haldane told them that men should be careful to retreat when they came to after-damp, but men did not know, except by the senses, when they got to after-damp after an explosion, simply because they had no means of detecting it, and the only suggestion made was to use a live mouse, but they could not expect a collier to take a mouse down the pit with him every day.

Dr. Haldane said it seemed to him that, "considering the risks of an explosion in any fairly dry pit, however free from fire-damp, arrangements should be made beforehand for minimizing, as far as possible, the loss of life should an explosion occur."* He (Mr. Hedley) did not think that they should allow that statement to pass without making some remarks upon it. In the first instance, as far as his experience went, arrangements were made beforehand in every well-organized pit to prevent explosions; and, secondly, after an explosion he thought he was justified in saying that arrangements were made, as far as possible, to prevent any serious results. The provision of light movable flaps on the top of the upcast shaft was already made and he thought that where fans were erected at the present day these movable flaps were, in nearly every instance, provided; and if they were not provided, it was not the fault of the colliery owner, but of the inspector of mines, who ought to see that it was done.

Another point to which Dr. Haldane referred was the death of men after an explosion, but he had evidently overlooked the fact that many men, although they were not blackened and burnt severely on the outside of their bodies, had inhaled the hot atmosphere, and this might result in their death at any time. In small explosions the men were not burnt or blackened with dust, and yet they died; it was a question of internal burning, and many deaths were no doubt due to that fact.

Referring to the Brancepeth explosion, the writer said that 90 per cent. of the victims would probably have escaped if there had been after-damp there, but in this he was surely mistaken. There were men killed, 8 being killed by injuries.

He thought that the members ought not to rush away and leave the old-fashioned systems of testing the gas for new ones unless they had per-

* *Trans. Fed. Inst.*, vol. xi., page 511.

certainty that these would be of benefit to them. They went into a pit in their own way to examine for gas, and knew how to find it with a safety-lamp. After an explosion they would enter the pit with their old friend, the safety-lamp, and any practical man was able to see whether he was going into danger or not, and could judge whether or not he was in a dangerous atmosphere. It did not matter what the percentage of oxygen was, he for one would certainly trust to that method in preference to anything else.

It was true that fires were often originated by an explosion, but it was extremely doubtful whether combustion was supported by oxygen left in the after-damp. Many years experience had shown that such fires simply smouldered until fed by fresh air supplied by the gradually increasing restoration of the ventilation.

Mr. JOSEPH DICKINSON (Manchester) said that he was very pleased with the practical remarks which Mr. Hedley had made, and he felt quite satisfied that in the discussion which the paper would elicit among so many able mining engineers as were members of The North of England Institute of Mining and Mechanical Engineers the whole thing would be thrashed out, and nothing in the nature of a mere toy would be thrust upon the miner when he had to face that difficulty and make his way as best he could among the after-damp. He would like to mention that the subject of carbonic oxide was once closely gone into in the case of the Hetton colliery explosion in the north of England, which, perhaps, very few of those present, except the President and himself, would remember anything about. Mr. Nicholas Wood called in the assistance of Sir Lowthian Bell and the late Dr. Thomas Richardson, of Newcastle, who stated that carbonic oxide was the most poisonous gas found in after-damp. He brought the subject before the Manchester Geological Society at the time, and it was very carefully discussed by the late Dr. Crace Calvert.*

He did not find any reference in the paper to the specific gravity of after-damp. He believed that the Royal Commission were of opinion that after-damp was of greater specific gravity than atmospheric air, and, consequently, that it should be lying on the ground, but in the many times he had had to face after-damp and clear it away, he had always found it next the roof, whether from originally lighter specific gravity or the heating which it had got by the explosion he would leave it to the chemists to decide. Very likely many of the members would go minutely into the various points of Dr. Haldane's paper, and some

* *Trans. Manch. Geological Society*, 1862, vol. ii., page 35.

practical rules would no doubt be laid down for the guidance of men in explosions. The old-fashioned rule that he was brought up with was "Make your way to the shaft, and if you find any obstruction by falls or pit-gas, go back and find another way, but do not go into the gas."

Dr. J. S. HALDANE (Oxford) acknowledged the force of Mr. Gerrard's caution as to the danger of fanning a smouldering fire into active flame by the too hasty introduction of fresh air, but he thought that a long delay in getting into the pit after an explosion increased the risk in another way, since small fires thus had time to assume serious dimensions, and large volumes of gas accumulated. This was at least the impression that he received from the facts recorded in the official reports of several explosions.

With regard to Mr. J. L. Hedley's remarks as to light movable flaps at the top of the upcast shaft being already generally provided, he thought that there must be some misunderstanding. In several recent explosions in new and thoroughly well-equipped pits the ventilation had for some time been arrested through the timbering connecting the fan-drift and the fan being blown out. At Tylorstown explosion, for instance, although the force up the upcast shaft hardly moved the pit-cover, which was, of course, somewhat heavy, yet much of the timbering was blown-out.

As to men being killed by inhaling the hot atmosphere, he had not himself hitherto met with such cases. He had carefully examined the air-passages of a number of dead horses for evidence of internal burning, but could not find any signs of scorching beyond the lips and tip of the tongue; nor did any survivors whom he had examined show definite symptoms of internal burning.

The statement which he had made as to the causes of death at the Brancepeth explosion was based on the medical examination of the bodies, which was conducted by Dr. Brown and himself. The appearances of the bodies were so characteristic that there could be no room for doubt as to carbonic oxide poisoning being the actual cause of death in at least 18 out of the 20 cases.

He was very much surprised at Mr. Hedley's trust in the indications of a safety-lamp, and at the expressions of apparent agreement with Mr. Hedley by the President and Mr. Dickinson. He thought that, quite apart from the facts brought forward in the paper, all would have been agreed as to the extreme danger of trusting to a safety-lamp in after-damp, or gases from underground fires, heated coal, etc. At Tylorstown, 11 men were found lying dead with lamps burning beside them, and at

Tylorstown, Brancepeth, and Micklefield, rescuers, whose lamps were burning brightly, were overcome, and narrowly escaped with their lives —to quote only instances observed during the present year.

He (Dr. Haldane) thought that the observations recorded by Mr. Dickinson as to the specific gravity of after-damp were most interesting. He (Dr. Haldane) had calculated that the after-damp of a dust explosion must be if anything lighter than air, but he had hesitated, in the absence of direct evidence, to make any positive statement on the subject in his paper. The after-damp is air, the oxygen of which has been replaced by nitrogen, carbon dioxide, carbon monoxide, aqueous vapour, and, probably, a little hydrogen and marsh gas distilled from the dust. The nitrogen, carbon monoxide, hydrogen, aqueous vapour, and marsh gas are all lighter than the oxygen which they replace, and will counterbalance the effect of the heavier carbon dioxide.

He was sorry he had not seen the paper referred to by Mr. Dickinson, and he feared that there might be other observations on the properties of after-damp which he had overlooked when writing his paper. He would like to take the opportunity of saying that the theory that carbon monoxide was the chief poisonous constituent of after-damp was in no way originated by himself, but he thought, nevertheless, that a closer investigation of the subject had been much required. The mere fact that safety-lamps would burn in the poisonous air was not sufficient proof as to the nature of the poison, since lamps would also burn in air rendered poisonous or dangerous by sulphuretted hydrogen, sulphurous acid, carbonic acid, and other gases.

He hoped that the mouse test would be practically used in dealing with gases from heated coal, after-damp, etc. In view of Mr. J. Dickinson's remarks on the specific gravity of after-damp, it might be well to add a caution as to the desirability of keeping the animal as high as the head of the man carrying it.

The PRESIDENT said that Dr. Haldane was somewhat diffident with regard to speaking practically on the subject, but he did speak medically, and his observations were entitled to the greatest possible respect. He (the President) agreed with Mr. Dickinson's and Mr. Hedley's remarks. The members were indebted to Dr. Haldane and must give to him their best thanks for taking the trouble to write this valuable paper.

Mr. D. H. F. MATTHEWS (H.M. Inspector of Mines) read the following paper, by Mr. H. Hall, on "Some Aspects of Recent Colliery Explosions":—

SOME ASPECTS OF RECENT COLLIERY EXPLOSIONS.

By H. HALL, H.M. Inspector of Mines.

The writer proposes to submit to the members a few thoughts on the initiation of colliery explosions as distinct from their development and extension, believing that this latter branch of the subject has recently had more than its share of attention, whilst the initiation has to some extent been overlooked.

He will direct attention more especially to the questions of open lights and blasting with powder, because it is from one or other of these two sources that the initial flame springs, which sets alight the fire-damp or coal-dust, and thus leads to those tremendous and disastrous effects with which we are all so familiar. There are, no doubt, one or two other sources of ignition, such as spontaneous combustion or accidental fires, but very few explosions have been traced to these agencies.

No one who takes an interest in the subject can fail to have been struck by the fact that colliery explosions which have happened recently have occurred in mines hitherto considered of the non-dangerous class. Mines in which, for instance, fire-damp is either unknown or presenting itself on very rare occasions, and at long intervals, and then only in such small amount as apparently to render an explosion of a devastating character, impossible. To satisfy ourselves that this has been so, we need only refer to the explosions at Camerton in Somersetshire, Blackwell in Derbyshire, Brancepeth in Durham, and Micklefield in Yorkshire, all of which collieries were looked upon as of so safe a character that open lights were used to work the coal, and blasting with gunpowder was resorted to wherever the coal or stone needed to be blown.

The circumstances of each of these explosions, and the character of the mine, may be shortly stated as follows:—

At Camerton, the explosion originated in an intake air-road, and is supposed to have been caused by a shot of blasting-powder fired there—the effects were visible over 3,600 feet of roads. There were 2 deaths. This colliery had been worked for upwards of one hundred years with open lights only. There was not such a thing as a safety-lamp on the premises. The seam in question is partially dusty. The jury found—

"that the deceased lost their lives through an explosion, but how that explosion was caused there was not sufficient evidence to determine"

At Blackwell, the explosion originated in an intake air-road, and is supposed to have been caused by a shot of blasting-powder fired there. The effects were sweeping, and were visible over considerable distances. There were 7 deaths. The seam was worked with open lights, and had been since its commencement; but safety-lamps were occasionally used, and more especially after any cessation of working, as on Sunday evening. The seam in question is partially dusty. The verdict of the jury was:—"We find that John Jones and six others met with their deaths on the 11th November, by an explosion in the low main seam at the A winning pit of the Blackwell Colliery Company, which explosion was caused by an overcharged shot of gunpowder; but the evidence fails to clearly define the secondary cause."

At Brancepeth, the explosion originated, also, in an intake air-road, and is supposed to have been caused by a shot of blasting-powder fired there. The effects were sweeping, extending over upwards of 3 miles of roads. There were 20 deaths. The colliery is worked with mixed lights, open lights being used in cutting or forming the pillars, and safety-lamps in working the "broken," and on all main roads. The seam in question is dusty. The verdict of the jury was:—"We find that a shot was fired (gunpowder), but by whom we know not, and the shot ignited the coal-dust, and caused an explosion in the cross-cut way, culminating in the deaths of 20 men and boys accidentally."

At Micklefield, the explosion was caused by an open light, and was very violent in character. The colliery had been worked with open lights during the past twenty-three years. There were 63 deaths. The verdict of the jury was as follows:—"We are unanimously of opinion that the explosion was caused by gas, and was purely accidental, and that no blame is to be attached to any person."

Now, three of these explosions have occurred within the last twelve months, and within that period there has been only one serious explosion in a mine of a dangerous class, namely, at Tylorstown, in Glamorganshire, where 57 persons were killed in January, 1896. The supposed cause of this explosion was the firing of a shot of some high explosive by means of tape-fuze.

Thus we see, that at any rate recently, explosions have been more frequent in mines of the supposed safe class than in others. In three of the cases referred to, a shot of blasting-powder is fixed upon as the

initiatory cause, but, as open lights were in use it must have been somewhat difficult to decide with certainty that the disasters were due to blasting.

If these were fire-damp explosions, then we naturally ask how it was that such a large body of gas, as must have been present to produce such effects, escaped being inflamed by the open lights, previous to the blasting taking place. The writer leaves this question to be answered by the opponents of the coal-dust theory.

In the cases quoted, we have a remarkable phenomenon of a devastating and sweeping explosion, under circumstances and surroundings which were deemed so devoid of danger that the simple precaution of using safety-lamps was not resorted to, and so far as human ingenuity could discover, by means of a searching enquiry, the conditions of the mines were precisely the same, as to safety, at the moment the explosions happened.

We see that in each of these recent explosions, either open lights or gunpowder has been the initiatory cause, and, if we examine the official statistics for 1895 we shall find some further startling evidence as to the part played by open lights in initiating explosions.

The writer has carefully taken out of the Reports of H.M. Inspectors of Mines, etc., for 1895, the particulars of all the fatal and non-fatal explosions of fire-damp or coal-dust in the United Kingdom, and they are as follows :—

TABLE I.—LIST OF FATAL AND NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN THE UNITED KINGDOM DURING THE YEAR 1895.

Districts.	Explosions of Fire-damp or Coal-dust.				Causes.		
	Fatal.	Deaths.	Non-fatal.	Injured.	Open Lights.	Gunpowder or Fuze.	Other Causes.
West of Scotland	2	14	47	66	46	—	3
East of Scotland	2	2	29	43	29	2	—
South Wales	7	10	29	43	34	1	1
South Staffordshire	2	4	10	15	10	—	2
Yorkshire	1	2	6	9	—	1	6*
Northumberland	1	1	5	7	6	—	—
South Western	2	9	2	2	2	2	—
Midland	1	7	3	5	2	2	—
North Staffordshire	—	—	4	7	2	2	—
West Lancashire and North Wales	1	1	3	9	—	2	2
North-East Lancashire ...	1	5	2	3	2	—	1
Durham	—	—	4	6	3	1	—
Totals	20	55	144	215	136	13	15

* Cause not stated, probably open lights.

N.B.—83 per cent. of those explosions were due to open lights, or 136 fatal and non-fatal explosions out of a total of 164. 52 per cent. of the deaths were caused by open lights, or 29 out of a total of 55.

The geographical distribution of these explosions is remarkable. We find that Scotland and South Wales have, in point of numbers, many more explosions than the English counties, indeed Scotland has almost twice as many as the whole of England taken together, her only competitor in this respect being South Wales. These two districts combined account for very nearly 50 per cent. of the deaths.

We need not be at a loss for an explanation of this singular state of things, because it is notorious that Scotland and the bituminous coal collieries of South Wales have adhered to open lights, while such lights have almost totally disappeared from the English counties, and thus we have the anomaly of more frequent explosions of fire-damp in mines popularly supposed to be least liable to the presence of fire-damp.

The year 1895 is by no means singular as regards explosions and their causes. The writer has summarized (Table II.) the whole of the deaths by explosions of fire-damp or coal-dust during the twenty-two years previous to 1895, and they amount to 4,914, of which number 1,583 deaths are set down to open and mixed lights, and 1,853 to blasting with powder or other flaming explosive, that is 70 per cent. of the total deaths have been due to these two causes combined. There are no statistics of the non-fatal explosions in these years, but they were, no doubt, even more frequent than in 1895, and their geographical distribution the same.

There is yet another fruitful source of accident in open light collieries, namely, by sparks from candles or open lamps coming accidentally into contact with charges of explosive, either in transit from place to place or in process of charging holes. If we examine the statistics for last year, we shall find that such accidents are very frequent and, although seldom fatal, they are usually of a very distressing nature.

A further danger springing from the use of open lights is the laxity of discipline which it always entails: men smoke, carry matches, and generally behave as if they were quarrying instead of mining; and these men having been taught habits of this kind move about the country, taking their bad habits with them, and become a constant source of danger and trouble in other districts. As a proof of the lamentable influence of such a training, we need only refer to the Official Report of Messrs. Guthrie and Ronaldson to the Secretary of State on an explosion in the Quarter colliery, Scotland, in April, last year. There were 13 persons killed, and on pages 3 and 4 of the report we find as follows:—

On the bodies of the other 8 men who were killed were found the following articles:—

TABLE II.—DEATHS CAUSED BY EXPLOSIONS OF FIRE-DAMP AND IGNITIONS OF GUNPOWDER FROM 1873 TO 1894 INCLUSIVE.

Inspection District.	1873.						1874.						1875.						1876.						1877.					
	Candles or Mixed Lights.	Blasting with Powder.	Detective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Detective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Detective Lamps or Flame passing Gauze.	Ignited by Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Detective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Detective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle ..	1						1						4						2						2					
Durham ..	2						1						1						2						3					
Manchester	1						6	15					2	3	1				2	1					2					
Liverpool ..	10	19	1	2	5	1	6				2		18	143		1	2		1	11			1		11	1			1	1
Yorkshire ..	5	1		4	1	2	28		1		4		1				4						4		22				2	
Midland ..	2	20	1		1	1	3				4		7	43	1		2		4				2		5				1	
North Stafford	2				1	5	78				4		22	96	2		2		19		1		2		2				2	
South Stafford	1				6	2	2	5			6	1	18	1			3		2				1		6				1	
South-western	5				3	1	6				3		1				2		1						3					
South Wales	7				1	4	3				1	1	5				1		3						1					
East Scotland	3				5		7				3		3				5		1						1					
West Scotland							3				1		3				1								1					
Newcastle ..	1						3				3		1	164			4		1				1		2				1	
Durham ..	2	3			1		1	1			1		2	9			1		3	4			1		2				1	
Manchester	45		195*		2		10				2		43	4			1		1		48*		1		2				1	
Liverpool ..	2	2		2	1		5				1		2	62	1		1		1	1			1		1				1	
Yorkshire ..	2	2			1		31				2		3	1			1		2				1		2				1	
Midland ..	2	26			2		1	1			1		6	120*			1		1				1		2				1	
North Stafford	2	2	208*		3		10			3	1		2	101			2		1				1		2				1	
South Stafford	3	3					6	28			1	63	3				2		3	1			1		2				1	
South-western	4	2			2		4	2			1		2				2		1				1		2				1	
South Wales	19	3			2		13				1		6				2		1				1		2				1	
East Scotland																														
West Scotland																														

TABLE II.—DEATHS CAUSED BY EXPLOSIONS OF FIRE-DAMP AND IGNITIONS OF GUNPOWDER FROM 1873 TO 1894 INCLUSIVE.—*Contd.*

Inspection District	1883.						1884.					
	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle	2	—	—	—	3	—	—	—	—	—	—	—
Durham	—	—	—	—	7	—	—	—	—	—	—	—
Manchester	6	—	68	—	—	—	2	—	—	—	—	—
Liverpool	1	2	—	—	1	—	1	—	—	—	—	—
Yorkshire	—	—	20	—	3	—	1	—	—	—	—	—
Midland	2	—	—	3	5	—	1	—	—	—	—	—
North Stafford	—	—	—	—	3	—	2	—	—	—	—	—
South Stafford	2	—	—	—	5	6†	16	—	—	—	—	—
South-western	2	—	—	—	2	—	2	—	—	—	—	—
South Wales	4	—	—	—	2	5	14	—	2	—	—	14
East Scotland	1	—	—	—	4	—	3	—	—	—	2	—
West Scotland	3	—	—	—	1	—	3	—	—	—	1	—

Inspection District	1885.						1886.					
	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle	180	—	—	—	1	—	1	—	—	—	1	—
Durham	1	—	—	—	1	—	1	—	—	—	1	—
Manchester	1	42	—	—	—	—	1	28*	—	—	—	—
Liverpool	1	—	—	—	—	—	2	—	—	—	—	—
Yorkshire	1	3	—	—	—	—	1	22	—	38	—	—
Midland	1	—	—	—	1	—	2	—	—	—	—	—
North Stafford	1	8	—	—	1	—	2	—	—	—	—	—
South Stafford	2	—	1	—	—	—	19	—	—	—	—	—
South-western	3	—	—	—	1	—	7	1	—	3	—	—
South Wales	2	—	—	—	2	—	—	—	—	—	—	—
East Scotland	3	—	—	—	1	—	—	—	—	—	—	—
West Scotland	2	—	—	—	—	9	10	—	—	—	—	—

Inspection District	1887.						1888.					
	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle	4	—	—	—	2	—	1	30	—	—	—	—
Durham	1	—	—	—	—	—	2	—	—	—	—	—
Manchester	1	8	—	—	2	—	1	—	—	—	—	—
Liverpool	3	—	—	—	1	—	2	—	—	—	—	—
Yorkshire	1	6	—	—	—	—	2	—	—	—	—	—
Midland	1	—	—	—	1	—	1	—	—	—	—	—
North Stafford	3	—	—	—	1	—	2	—	—	—	—	—
South Stafford	1	39	—	—	2	—	7	—	—	2	—	—
South-western	1	74	—	—	4	—	1	—	2	—	—	—
South Wales	1	—	—	3	—	—	1	—	—	—	—	—
East Scotland	1	—	3	—	—	—	1	—	—	—	1	—
West Scotland	1	—	—	—	—	—	5	—	—	—	—	—

Inspection District	1889.						1890.					
	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle	—	6	—	—	3	1	—	—	—	—	5	—
Durham	—	—	—	—	3	—	—	—	—	—	3	—
Manchester	—	—	—	—	1	—	2	—	—	—	—	—
Liverpool	2	—	20	—	—	—	1	—	—	—	1	—
Yorkshire	2	—	—	—	—	—	2	—	—	—	1	—
Midland	—	—	—	—	1	—	—	—	—	—	1	—
North Stafford	26	—	—	—	1	64‡	182	—	—	—	—	—
South Stafford	4	—	—	—	1	—	4	—	—	—	—	—
South-western	5	—	—	—	1	—	5	87	—	—	3	—
South Wales	2	—	—	—	3	—	6	—	—	—	6	—
East Scotland	1	—	—	—	3	—	3	—	—	—	3	—
West Scotland	4	1	—	—	6	—	5	—	—	—	3	—

Inspection District	1891.						1892.					
	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle	5	—	—	—	2	—	1	1	—	—	—	—
Durham	—	—	—	—	2	—	—	—	—	—	—	—
Manchester	—	29	—	—	2	—	—	—	—	1	—	—
Liverpool	2	—	—	—	3	—	—	—	—	—	—	—
Yorkshire	2	10	—	—	4	—	—	—	—	—	—	—
Midland	—	—	—	—	1	—	—	—	—	—	—	—
North Stafford	14	—	—	—	1	—	2	—	—	—	—	—
South Stafford	—	1	—	—	2	—	—	—	—	—	—	—
South-western	3	—	—	—	1	—	1	—	—	112	—	—
South Wales	2	—	—	—	2	—	—	—	—	—	—	—
East Scotland	1	—	—	—	2	—	4	—	—	—	—	—
West Scotland	1	—	—	—	5	—	1	—	—	—	—	—

Inspection District	1893.						1894.					
	Candles or Mixed Lights.	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.	Candles or Mixed Lights	Blasting with Powder.	Defective Lamps or Flame passing Gauze.	Ignited at Furnace.	Accidental Ignitions of Gunpowder.	Cause not stated.
Newcastle	2	2	—	—	—	—	2	—	—	—	—	—
Durham	—	—	—	—	—	—	—	1	—	—	—	—
Manchester	142	—	—	—	—	—	—	—	—	—	—	—
Liverpool	2	—	—	—	—	—	—	—	—	—	—	—
Yorkshire	1	—	—	—	—	—	—	—	—	—	—	—
Midland	3	2	—	—	—	—	—	—	—	—	—	—
North Stafford	—	—	—	—	—	—	—	—	—	—	—	—
South Stafford	—	—	—	—	—	—	—	—	—	—	—	—
South-western	1	—	—	—	—	—	—	—	—	—	—	—
South Wales	38	—	—	—	—	—	—	—	—	—	—	—
East Scotland	—	—	—	—	—	—	—	—	—	—	—	—
West Scotland	—	—	—	—	—	—	—	—	—	—	—	—

* Not conclusive. † Gob-fire. ‡ Possibly gob-fire. ‖ Gelatine-dynamite. § Opened a safety-lamp.

No. 1.—Tin matchbox, half-full of matches, and contrivance for opening lamps.
No. 2.—Split nail for opening lamps.
No. 3.—Seven matches and split key for opening lamps.
No. 4.—Split nail for opening lamps.
No. 5.—Clay pipe and a piece of tobacco.
No. 6.—Tin matchbox, half-full of matches.
No. 7.—Clay pipe and piece of tobacco.
No. 8.—Wooden pipe, piece of tobacco, one match, and a box half-full of matches.

This colliery was worked with open lights up to six years ago, but at that time, as the result of an arbitration, safety-lamps were adopted. It is clear that six years had not sufficed to eradicate the early teaching.

Such are the facts to which the writer desires to draw attention, they are plain, unvarnished facts, gathered from dry official reports, and for that reason sometimes overlooked: at any rate their accumulated significance is not always appreciated. The list is black enough in all conscience, and if we ask ourselves why a system, producing such disastrous results, has not been swept away long ago, the question is somewhat difficult to answer. It is held by the advocates of the prehistoric candle, that falls of roof are prevented by the better light afforded. This may have been so when the only competitor of the candle was a Davy safety-lamp, but it is no longer true in the presence of improved safety-lamps giving a superior light to that even of the candle. We are also told that, with open lights in general use throughout a mine, there can be no sweeping explosion, but this view has been belied again and again. Also the continued use of open lights is at times upheld on the ground that they have been used twenty or thirty years in a particular mine and nothing serious has happened. Such a view seems reasonable at first sight, but we must bear in mind that, if an explosion were to happen in every colliery in its life of forty or fifty years, we should have large colliery explosions almost daily, instead of only two or three in a year.

Economy, may be put forward by some engineers as a sufficient reason, but this opinion will hardly be shared by the profession generally. I would be quite as reasonable for a railway company to decline to put down a double line of rails on the score of expense, as it would be for a colliery company to refuse to adopt precautions on similar grounds.

The writer feels sure he is expressing the opinion of every engineer present when he states that nothing can justify the use of open lights in coal-mines, unless the previous history of the mine is such that we can satisfy ourselves with absolute certainty that fire-damp will never ma-

its appearance, and it is just this that the writer submits is impossible: he holds that no such unerring judgment can be formed, and that it is worse than folly to attempt to discriminate as to methods of lighting.

The managers of the four collieries to which attention has been drawn never dreamt that any such disaster as did happen was possible in their mines, or these would not have been worked with open lights for a single day, but events showed that they had made a sad and fatal mistake; and in addition to these recent explosions we have the long list of accidents under similar circumstances, which have been tabulated in this paper, all pointing to the same conclusion.

It has been too much the fashion in the past to wrap in mystery the circumstances of colliery explosions, and to assume a fatalism which really does not exist. In at least three cases out of four the cause of the initiation of an explosion is transparent, and easily removable, and their continued recurrence from the same cause is a slur on the profession of mining engineers. Institutes such as this meet from time to time, and the members are complimented by the President on the rapid advance that the science of mining is making, Royal Commissions sit and report with elaborate detail, and men to the front in the scientific world are called in to elucidate the question as to whether the victims die from the effects of carbon monoxide or carbon dioxide, whilst, all the time, we apparently close our eyes to glaring facts, and are content to remain in a position of apathy.

The mining profession, and especially the members of such an Institute as this, should not require to be coerced, either by Parliament or any other outside influence, but should, of their own motion and as a matter of prestige, take action to put an end to practices which are a flagrant breach of good mining.

The writer is satisfied that a large majority of the men who have to carry out the actual management of the mines are ready to give a decisive vote against the continuance of both open lights and blasting-powder; but they are held back by influences which are somewhat difficult to define. There is the constant pressure put upon them to produce cheaply, a matter, by the way, to which much more importance seems to be attached than to the disposal of the produce at remunerative prices. But it must be the true policy of all interested to make the calling of the miner a safe one, so that no premium need be paid in the form of high wages as a set-off against risk.

There is also the insidious influence that springs from the fact of a close governmental control, such as is exercised over mining operations,

always tending to a waiting and somewhat apathetic attitude, and this being so, a government should be quite sure that its legislation keeps pace with the highest standard of professional practice.

But, whatever force such influences may have, and from whatever quarter they may come, we mining engineers who love our profession and respect ourselves should oppose a resolute front to every influence which might place us in a position where reflexions might be justly cast upon our skill or humanity.

The PRESIDENT said that there were some members as old as himself who remembered the condition of things when they had corves and cranes going, and where, in consequence, the amount of dust in the roadways was infinitely greater than at present. Under such circumstances, and especially in pits where gas and a high temperature prevailed, one wondered now that there were not explosions almost daily. The members must not think for a moment that he was an advocate for the other side, and that coal-dust did not contribute largely to the increase of the death-rate in mines. He had long entertained the opinion that coal-dust did exercise a large influence. He was not quite a convert to the idea that every accident would be considered as due to coal-dust alone, simply because gas may not have been seen over a long period. Wherever, however, they had gas or coal-dust even in very small quantities they should take precautions of the character which had been indicated, and he was sure that coal-owners had the matter sufficiently in hand to do all they could to remedy the state of things that prevailed in the past. There were exceptions, but he gave colliery owners, as a rule, the credit of doing everything that they could to prevent accidents in their own collieries. It required no pressure from the Government to bring that about. They might have too much legislation. They should depend more upon themselves than upon what legislation could do, and papers of this kind, from further experience gained, would, no doubt, lead them shortly to obtain a more correct knowledge of the influence of coal-dust.

Mr. C. M. PERCY (Wigan) said that he was a strong advocate, in his feeble way, for the views which the author of the paper so strongly advocated. He quite agreed that many colliery owners—and Lancashire stood well in that respect—required no legislation, but they must not

think, or tend in the direction of thinking, that because there were some righteous colliery owners there must be no legislation. There were many who required no laws and who would lead an upright life if there were no laws, but the law was brought into operation to correct the sinner, not the saint. The legislation of the past had proved so enormously beneficial that it was an encouragement for further legislation, and speaking more as an outsider than an insider in mining matters, he must admit that the public feeling was very strong that these explosions, from whatever cause, ought to diminish and that further legislation was necessary. Legislation in the matter of lighting and explosives would bring, not those colliery owners who did their duty, but those who did not do their duty, to their senses, and would lessen the devastation in the mines of this country.

The PRESIDENT moved that the thanks of the members be accorded to Mr. Hall for his valuable paper.

Mr. W. J. ORSMAN read the following paper on "Notes on the Explosion of Coal-dust":—

NOTES ON THE EXPLOSION OF COAL-DUST.

By W. J. ORSMAN, F.I.C., F.C.S.

It is curious to note that nearly all the recent explosions in British collieries have been traced to the ignition of coal-dust. As it is only lately that coal-dust has been recognized as a serious danger, it may be that in the olden days fire-damp was often wrongfully accused. Anyhow, the circumstances which guide the working of a mine at the present time are much more favourable to the explosion of coal-dust than of fire-damp.

With the modern methods of ventilation, any gas occluded from the coal ought to be at once swept away, or so diluted as to become a non-explosive mixture; on the other hand the current of air, sweeping up the dust, and presenting a large volume of oxygen, is distinctly in favour of helping to initiate and propagate a dust-explosion.

It is now an acknowledged fact that a mixture of coal-dust and air can be ignited and cause explosion without the help of marsh gas, and experiments on a large scale by Mr. Henry Hall, H.M. Inspector of Mines, and Mr. W. Galloway, have demonstrated that such explosions can be caused by means of a blown-out shot.

It is well known that explosions have occurred in flour-mills, and other places, in which a dusty atmosphere has been present, but these are of very rare occurrence, and it is a matter of extreme difficulty to cause an ignition of dust by means of a naked flame. If such ignitions were easy, we should have constant explosions in the dusty atmospheres in coal-mines where naked lights are used. We therefore have to look for some further explanation for the disastrous explosions which sometimes occur in mines, in which, as far as could be proved, no inflammable gas was found, either before or after the explosion.

The easiest way to produce an explosion of dust experimentally is by means of a blown-out shot of blasting-powder, that is to say, by firing a charge of blasting-powder in a cannon and allowing the heated products of combustion to come in contact with a dusty atmosphere. Under these circumstances, nearly every variety of coal-dust will catch fire and burn easily.

Gunpowder has been, and is still, used largely for blasting purposes, a special variety called blasting- or mining-powder being employed. Blasting-powder contains less saltpetre and more charcoal than ordinary gunpowder, and is therefore cheaper to use.

With ordinary blasting-powder, on firing, a large volume of heated gas is formed (about 3,000 times the volume of the powder used at the temperature of ignition), and no less than 50 per cent. of the total products of combustion, consisting of finely-divided particles of solid matter raised to a state of incandescence are projected from the bore-hole. These heated particles cause rapid ignition of a mixture of air and coal-dust.

Prof. H. B. Dixon has shown that the tendency of hydrocarbons, and probably carbon, when burnt in air, is to first form carbon monoxide, and that this gas, if excess of oxygen be present, further burns to form carbon dioxide. Prof. Dixon has also shown that carbon monoxide forms explosive mixtures with air and oxygen, the velocity of the explosive wave formed reaching a maximum in the presence of about 5 per cent. of water-vapour. The heat of combustion of one gramme of carbon burning to form carbon dioxide is 8,080 units; and in burning to form the monoxide is only 2,473 units; the difference, therefore, of 5,607 will show the number of units of heat evolved in the burning of the monoxide to the dioxide.

Prof. Vivian Lewes has demonstrated the fact that coal-dust will readily burn in mixtures of air and carbon monoxide, and has shown that a small proportion of carbon monoxide present in a dusty atmosphere will constitute a most explosive mixture.

There is every probability therefore that the initial combustion of the dust through contact with the heated products of the blown-out blasting-powder shot produces a certain quantity of carbon monoxide gas, and this gas mixing with the fresh air and fresh dust in the presence of flame will cause the explosion to rapidly extend in area.

With blasting-powders containing an excess of charcoal we find that large volumes of carbon monoxide and sulphuretted hydrogen are formed, and it can be easily demonstrated that coal-dust burns readily in mixtures of air with the gases produced in this way.

In order to test the action of the gases given off on the combustion or detonation of explosives containing an excess of carbonaceous matter, such as blasting-powder, carbonite, etc., small cartridges have been fired in a specially constructed steel bomb, and the gas produced has been mixed with air in a large cylinder. On sprinkling coal-dust inside and applying a light, the dust ignited easily, and burnt away fiercely. It will be seen,

therefore, that the presence of carbon monoxide in the air of a mine in small quantities is not only dangerous to health (1 per cent. being fatal), but also constitutes, when in the presence of coal-dust, a most explosive mixture.

On examining the other explosives now coming into use, it is found that those which do not produce carbon monoxide or other inflammable gases, such as those of the Sprengel class, containing nitrate of ammonium, are very safe in dusty mines, whilst others which produce inflammable gases are as dangerous as gunpowder.

From theoretical consideration and practical experiments, it is evident that safety-lamps are as necessary in a pit perfectly free from gas, where certain explosives are used, as in fiery mines, for suppose a shot of highly carbonaceous powder or other explosive, containing an excess of carbon, be fired in a bore-hole properly stemmed, and then a naked light be brought near the face where the coal has fallen, it is quite possible to get an explosion from the admixture of air with the gaseous products of combustion, and the explosion in a dusty atmosphere might extend with awful rapidity.

Apart from the dangers of explosion, the presence of the poisonous carbon monoxide gas produced from certain explosives, as shown in a previous paper read before the Institute some time ago, is highly deleterious to the health of the miner, and it is a matter of great interest that Dr. Haldane has determined to work on this subject.

In order to obtain some idea of the condition of the air inside the pit whilst an explosion was in progress, the author arranged, at the time of Mr. Hall's experiments in 1892,* a method of taking samples of the air. Two brass tubes, filled with water, were fastened to the rope that was used to lower the cannon, one 60 feet and the other 120 feet from the bottom. These tubes were so arranged and constructed, that the explosion, as it passed the tubes, unsealed the outlet pipe, and the escaping water allowed the ingress of a sample of air, which was trapped by a special arrangement and kept in the tube until the rope could be wound up. By this method it was intended that the sample of gas taken should represent the state of the air whilst the flame was passing, or directly afterwards. The lower tube, as the analysis will show, did partly collect the gas in the above condition. The tube at the top, however, commenced to act prematurely, and was probably started by the sound-wave which preceded the explosion. This tube simply con-

* *Report of the Royal Commission on Explosions from Coal-dust in Mines*, page 151.

tained ordinary air. The following is an analysis of the gases found in the lower tube :—

	Per Cent.
Oxygen	3·9
Nitrogen	75·9
Carbon dioxide	12·1
Carbon monoxide	8·1

The presence of carbon monoxide in the after-damp from an explosion would, by leaking into the side workings, in the absence of proper ventilation, account for miners being found dead, although the lamps continued to burn brightly, the percentage of carbon monoxide necessary to cause death having little or no effect on the flame of the lamps.

Many theories are held regarding the propagation of an explosion in a dusty mine, the principal one being that the coal-dust by the action of heat becomes distilled and yields the inflammable gases necessary to continue explosion. The production of these gases may undoubtedly have some effect, but the writer is firmly of opinion that the propagation is principally due to the continuous production of carbon monoxide, which causes rapid combustion of dust and air as long as these are present. It is found that lamp-black and other finely-powdered forms of carbon burn in the presence of carbon monoxide as easily as coal-dust. Further, all coal-dusts are sensitive to a blown-out blasting-powder shot, provided they are in a fine state of division, and free from any large admixture of dirt.

The reason why certain dusts have been stated to be safe, because they did not catch fire when experimentally tried, is due to the fact that they were contaminated with dirt, owing to the traffic through the pit, and so yielded a large percentage of ash.

Mr. ORSMAN, after reading the paper, made a few experiments with blasting-powder from the Blackwell colliery, showing that the gas produced by the ignition of the blasting-powder contained a large proportion of carbon monoxide and other gases, and also how readily such gases when mixed with air, promoted the ignition of coal-dust.

The PRESIDENT moved that a hearty vote of thanks be accorded to Mr. Orsman for his paper.

Mr. N. R. GRIFFITH read the following paper by Messrs. F. Brady, G. P. Simpson, and N. R. Griffith, on "The Kent Coal-field" :—

THE KENT COAL-FIELD.

By F. BRADY, M. INST. C.E.; G. P. SIMPSON, F.R.G.S.; and NATH. R. GRIFFITH.

Many years ago the late Mr. R. A. C. Godwin-Austen expressed an opinion, based upon theoretical considerations, that Coal-measures might possibly extend below the south-eastern parts of England, and in his report to the Royal Commission on Coal in 1871, Sir Joseph Prestwich adopted the view "that there is the highest probability of a large area of productive Coal-measures existing under the Secondary rocks of the South of England." He further expressed the opinion that the length of this supposititious coal-basin might extend to 150 miles, with a breadth of from 2 to 8 miles.

A boring, instituted and superintended by Mr. Francis Brady, the engineer to the South-Eastern Railway and the Channel Tunnel Company, one of the authors of this paper, at Dover, with the co-operation of Sir E. W. Watkin, has established the accuracy of the judgment of Sir Joseph Prestwich and Mr. Godwin-Austen as to the existence of the coal-basin.

This bore-hole is on the Great Fall at the foot of Shakespear Cliff, and a section of it accompanies this paper (Appendix A).

With regard to the origin of the Dover boring, it may be mentioned that the probability of a connexion between the Bristol and the Pas-de-Calais coal-fields, taking its course by way of Dover, became a subject of discussion shortly after the publication of the *Coal Commission Report* in 1871. This discussion was continued in 1874, at the time of the negotiations between Sir Edward Watkin and the promoters of the St Margaret's Bay Channel Tunnel Scheme, and also during the progress of the tunnel works in 1881 and 1882. When the further driving of the submarine trial-heading was interdicted, in July, 1882, by Mr. Chamberlain, then President of the Board of Trade, Mr. Brady, the Channel Tunnel Company's engineer, suggested to the chairman, Sir E. W.

Watkin, that the coal question could be tested by himself with the men retained under him to maintain the Channel Tunnel works; and the coal-boring was eventually authorized accordingly.

The position of this work is favourable for pit-sinking, being on the outcrop of the impermeable grey chalk, west of Shakespear Tunnel, Dover, at the point which was selected as the best site for the Channel Tunnel works by Mr. Brady in 1874.

Before commencing to bore, a shaft was sunk, for convenience in handling the rods, from the surface to sea-level, a depth of 44 feet, and the bore-hole was put down from the bottom of this shaft. The bore-hole was commenced 18 inches in diameter, on the percussion system of boring. After passing through the first seam of coal the diamond boring system was adopted, the bore-hole then being 9 inches in diameter. The last core brought up from the depth of 2,330 feet below the surface was 4 inches in diameter. Specimens of the cores are on the table, from which it will be seen that in the Coal-measures the stratification is horizontal.

As will be seen by the section, the depth from the surface to the top of the Coal-measures is 1,157 feet, and the bore-hole below this depth through 1,173 feet of Coal-measures passed through seams containing the following thicknesses of coal (omitting seams less than one foot in thickness):—

	Ft.	In.		Ft.	In.
1	2	6	7	2	3
2	2	0	8	2	9
3	2	0	9	1	8
4	1	3	10	4	0
5	1	0			
6	2	6	Total	21	11

In seams from 2 up to 4 feet in thickness there are 18 feet of coal which may fairly be considered workable. In addition, the seam 1 foot 8 inches thick, is also probably workable. With regard to the question whether there are likely to be other seams below the 4 feet seam, the fossil imprints brought up in boring were submitted to Mr. R. Zeiller, Lecturer on Vegetable Palæontology to the School of Mines, Paris. His report is appended to this paper, and it will be seen that from the presence of *Neuropteris rarinervis* and *Neuropteris Scheuchzeri* he concludes that the beds traversed by the boring belong to the upper region of the Middle Coal-measures. There is therefore good reason to anticipate that a very considerable thickness of productive Coal-measures will be found below the 4 feet seam.

With reference to the question of an original connexion between the coal-fields of Somerset and Belgium, and its probable course, Sir Joseph Prestwich, in his report of 1871 to the Coal Commission, said :—

We know that the great original coal-trough has been broken up into separate basins. The direction of this trough is, we think, likely to be on a line passing through North Wilts and Oxfordshire, thence across Hertfordshire, South Essex, and the north-eastern extremity of Kent onwards towards Calais. Or, in case of the anticlinal axis taking a more southerly course, we should look for the coal-basin or basins along a line passing from Radstock, through the Vale of Pewsey, and thence along the North Downs to Folkestone.

As we have now the evidence of numerous borings to prove the existence of a range of rocks older than the Carboniferous running east and west underneath London, and also know that the horizontal character of the seams found at Dover, together with the clean, bright, and uniform quality of the coal, indicate a central position in the coal-basin, it will be tolerably safe to assume that future coal-explorations should follow a nearly direct westerly course from Dover towards Bristol, as shown by a dotted line on the accompanying map (Plate XXIX.).

PARTICULARS OF BORINGS MARKED ON MAP (PLATE XXIX.).

DOVER BORING.

	Feet.
Grey Chalk and Chalk Marl ...	174
Chloritic Marl	8
Gault	121
Lower Greensand, Wealden and Hastings Beds	241
Upper, Middle, and Lower Oolites, etc., with Lias at bottom ...	613
Coal-measures with 8 workable seams 2 to 4 feet in thickness, containing 18 feet of bright bituminous coal...	1,173
	2,330

CALAIS BORING.

	Feet.
Alluvium	85
Eocene Beds	161
Chalk	765
Gault	26
Lower Greensand	65
Carboniferous rocks (thickness unproved)	
	1,102

CHATHAM BORING.

	Feet.
Alluvium	15
London Clay, etc.	12
Chalk	682
Gault	193
Lower Greensand	41
Middle Oolite (thickness unproved)	
	943

SHEERNESS BORING.

	Feet.
Alluvium	47
London Clay, etc....	307
Woolwich and Reading Beds ...	148
Chalk	303
	805

CROSSNESS BORING.

	Feet.
Alluvium	39
Eocene Beds	97
Chalk	638
Upper Greensand	65
Gault	176
Old Red Sandstone (thickness unproved)	
	1,015

MEUX'S BORING (Oxford Street).

	Feet.
Alluvium	22
London Clay, etc.	136
Chalk	655
Upper Greensand	28
Gault	160
Lower Greensand	64
Upper Devonian rocks (thickness unproved)	
	1,065

TURNFORD BORING.

	Feet.
Alluvium	20
London Clay, etc.	80
Chalk	700
Upper Greensand	20
Gault	164
Old Red Sandstone (thickness unproved)	
	984

RICHMOND BORING.

	Feet.
Alluvium	10
Eocene Beds	242
Chalk	670
Upper Greensand	16
Gault	201
Lower Greensand	10
Lower Oolite	88
Red rocks (probably Devonian) (thickness unproved)	
	1,237

WARE BORING.

	Feet.
Alluvium	14
Chalk	544
Upper Greensand	77
Gault	160
Silurian rocks (thickness unproved)	
	795

BURFORD BORING.

	Feet.
Great and Inferior Oolite ...	148
Lias	598
Rhætic Beds	10
New Red Sandstone	428
Carboniferous rocks	225
	1,409

The length of unexplored country lying between Dover and the great coal area, which originally included the South Wales, Somerset, and Forest of Dean fields, is about 160 miles. The Carboniferous rocks found at Burford lie too far to the northward to be taken into consideration in this connexion.

The horizontal bedding of the Coal-measures at Dover indicates that the boring is at some distance from the great Palæozoic east-and-west fracture which traverses Belgium and Northern France, and probably passes beneath the bed of the Channel south of Folkestone, in its course westward to the Mendip Hills.

The Dover coal of the lower seams compares well with thirty-seven samples of Welsh, which were analysed for the Government by Sir H. de la Beche and Dr. Lyon Playfair, the following being the comparison :—

Description of Coal.	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Heating Power. Units.
Dover, coal in lower seams ...	83·80	4·65	0·97	3·23	14,8
Welsh, 37 samples of coal required for Royal Navy	83·78	4·79	0·98	4·15	14,8

The comparison with Midland and North country coals suited for
Royal Navy, and analysed by the same two gentlemen in 1850, is e
more favourable, as shown below :—

Description of Coal.	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Heat Pow Uni
Coal from Dover boring	83·80	4·65	0·97	3·23	14,8
Newcastle, 18 samples	82·12	5·31	5·31	5·69	14,8
Derbyshire and Yorkshire, 7 samples	79·68	4·94	1·41	10·28	13,8
Lancashire, 28 samples	77·90	5·32	1·30	9·53	13,9

The Secondary strata passed through before reaching the C
measures gave no indications of the presence of water in sufficient vol
to cause serious difficulties in sinking. The impermeable Grey Chalk
the Gault below it appear to shut out the sea effectually from the lo
beds; the clays as a rule were found to be dry, and the sands so
The worst ground was met with at a short distance below the Weal
Beds.

A shaft 17 feet in diameter in the clear was commenced on the G
Fall by Mr. Brady, and carried down 82 feet, that is to about 40
below sea-level, meeting with very little water. The sinking of
shaft is being continued by the Kent Coal-fields Syndicate, Ltd.,
are about to commence immediately the sinking of a second shaft, 20
in diameter in the clear, at a distance of 120 feet from No. 1 shaft
well as the erection of plant and machinery for a large output of coal.

APPENDIX A.—Section of Diamond-boring from the Bottom of Sh
sunk 44 Feet to the Level of High Water of ordinary Spring T
at Shakespear Cliff, Dover.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Bottom of Shaft. Ft.	In.
1	Lower Grey Chalk	91	0	91	0
2	Indurated Chalk Marl	39	0	130	0
3	Chloritic Marl ...	8	0	138	0
4	Light-coloured Gault	48	0	186	0
5	Dark blue Gault...	70	0	256	0
6	Sandy Gault ...	3	0	259	0
7	Sandstone ...	5	0	264	0
8	Cherty limestone	2	0	266	0
9	Dark green and black silty sand	20	0	28	0
10	Blue grey clay ...	17	0	30	0
11	Greensand ...	4	0	30	0
12	Black sandy clay	14	0	32	
13	White sand and sandstone ...	2	0	32	0
14	Dark grey laminated silt and sand	37	0	36	0
15	Strong brown clay	19	0	37	

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Bottom of Shaft. Ft.	In.
16	Fine white silt ...	1	0	380	0
17	Dark grey carbonaceous marl ...	13	0	393	0
18	Black laminated shale	7	0	400	0
19	Siliceous silt ...	6	0	406	0
20	Calcareous grit ...	3	0	409	0
21	Silty clay... ...	18	0	427	0
22	Limestone ...	2	0	429	0
23	Calcareous sandstone	1	0	430	0
24	Shale	14	0	444	0
25	Limestone ...	1	0	445	0
26	Marl	5	0	450	0
27	Compact limestone	2	0	452	0
28	Quartz-pebbles ...	1	0	453	0
29	Marl	4	0	457	0
30	Limestone ...	5	0	462	0
31	Siliceous silt ...	6	0	468	0
32	Dark grey clay ...	5	0	473	0
33	Limestone ...	8	0	481	0
34	Marl	4	0	485	0
35	Limestone ...	2	0	487	0
36	Marl	7	0	494	0
37	Sandstone ...	3	0	497	0
38	Marl	3	0	500	0
39	Grey nodular limestone	4	0	504	0
40	Grey marl ...	1	0	505	0
41	Calcareous grit ...	3	0	508	0
42	Compact grey sandstone	4	0	512	0
43	Oolitic limestone	7	0	519	0
44	Compact grey sandstone	1	0	520	0
45	Oolitic limestone	7	0	527	0
46	Grey siliceous limestone	8	0	535	0
47	Compact sandstone	2	0	537	0
48	Grey marl ...	2	0	539	0
49	Compact grey limestone	1	0	540	0
50	Brown calcareous sandstone ...	2	0	542	0
51	Shelly conglomerate	1	0	543	0
52	Dark grey marl ...	2	0	545	0
53	Hard blue limestone	1	0	546	0
54	Brown rubbly sandstone full of brown polished "millet seed" grains	12	0	558	0
55	Grey lenticular limestone ...	4	0	562	0
56	Dark grey bituminous clay ...	8	0	570	0
57	Flaggy sandstone	2	0	572	0
58	Grey sandy clay...	4	0	576	0
59	Hard arenaceous limestone ...	7	0	583	0
60	Blackish-grey bituminous marl with white shelly partings	27	0	610	0
61	Grey nodular limestone, partly crystalline ...	2	0	612	0
62	White coral rag, partly crystalline	42	0	654	0
63	Clayey limestone	3	0	657	0
64	Compact grey limestone, partly crystalline ...	6	0	663	0
65	Lenticular sandstone	2	0	665	0
66	Compact grey limestone	1	0	666	0
67	Brown lenticular sandstone	1	0	667	0
68	Grey compact limestone, partly translucent ..	5	0	672	0
69	Nodular sandstone	1	0	673	0
70	Crystalline limestone	7	0	680	0
71	Arenaceous limestone	4	0	684	0
72	Nodular sandstone	1	0	685	0
73	Grey earthy limestone	4	0	689	0
74	Sandy marl ...	1	0	690	0
75	Grey earthy limestone	15	0	705	0
76	Sandy marl ...	1	0	706	0
77	Hard grey earthy limestone ...	33	0	739	0
78	Marly clay ...	7	0	746	0
79	Shelly limestone ..	3	0	749	0
80	Sandy clay ...	2	0	751	0
81	Compact limestone	1	0	752	0
82	Sandy clay ...	3	0	755	0
83	Blue compact limestone	1	0	756	0
84	Sandy clay ...	3	0	759	0
85	Grey arenaceous limestone ...	10	0	769	0
86	Dark sandy marl	6	0	775	0
87	Sandstone ...	2	0	777	0
88	Black marl ...	2	0	779	0
89	Sandstone ...	1	0	780	0
90	Earthy marl ...	5	0	785	0
91	Sandstone and shells	1	0	786	0
92	Brown sand and earth	6	0	790	0
93	Calcareous sandstone	3	0	795	0
94	Silty shale and marl	43	0	838	0
95	Marly limestone	1	0	839	0
96	Laminated marl...	7	0	846	0

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Bottom of Shaft. Ft.	In.
97	Concretionary rock with broken shells	2	0	848	0
98	Dark grey hard marl	34	0	882	0
99	Marly limestone...	1	0	883	0
100	Brown sandy marl	22	0	905	0
101	Calcareous sand...	2	0	907	0
102	Reniform sandstone	3	0	910	0
103	Brown sandy clay	1	0	911	0
104	Brown sandstone	4	0	915	0
105	Calcareous sand...	3	0	918	0
106	Hard grey limestone	3	0	921	0
107	Calcareous sand...	1	0	922	0
108	Brown sandstone	4	0	926	0
109	Calcareous sand...	3	0	929	0
110	Lenticular sandstone	2	0	931	0
111	Earthy clay ...	4	0	935	0
112	Calcareous sand...	3	0	938	0
113	Dark grey marl ...	2	0	940	0
114	Bluish-grey clay...	12	0	952	0
115	Brown sand ...	1	0	953	0
116	Hard grey marl ...	4	0	957	0
117	Shelly limestone...	2	0	959	0
118	Grey marl ...	4	0	963	0
119	Siliceous limestone	3	0	966	0
120	Sandstone ...	1	0	967	0
121	Marl	1	0	968	0
122	Shelly limestone...	1	0	969	0
123	Carbonaceous marl	5	0	974	0
124	Earthy limestone	1	0	975	0
125	Marl	2	0	977	0
126	Sandstone ...	1	0	978	0
127	Oolitic limestone	8	0	986	0
128	Sandstone ...	1	0	987	0
129	Whitish Oolitic limestone with shell fragments	9	0	996	0
130	Marl	2	0	998	0
131	Whitish Oolitic limestone with shell fragments	15	0	1,013	0
132	Calcareous sand...	5	0	1,018	0
133	Hard grey limestone	14	0	1,032	0
134	Sand	1	0	1,033	0
135	Hard limestone ...	3	0	1,036	0
136	Calcareous sand...	1	0	1,037	0
137	Dark grey limestone	10	0	1,047	0
138	Calcareous sand...	1	0	1,048	0
139	Dark grey marl ...	5	0	1,053	0
140	Calcareous grit ...	3	0	1,056	0
141	Flaggy sandstone	3	0	1,059	0
142	Calcareous grit ...	4	0	1,063	0
143	Dark grey hard sandstone ...	13	0	1,076	0
144	Hard grey clay ...	7	0	1,083	0
145	Dark grey compact limestone ...	2	0	1,085	0
146	Dark grey marl ...	1	0	1,086	0
147	Grey argillaceous limestone ...	3	0	1,089	0
148	Marl	1	0	1,090	0
149	Compact grey limestone	1	0	1,091	0
150	Marl	1	0	1,092	0
151	Hard grey limestone	1	0	1,093	0
152	Marl	1	0	1,094	0
153	Compact grey limestone	2	0	1,096	0
154	Blackish-grey clay	5	0	1,101	0
155	Earthy limestone	1	0	1,102	0
156	Blackish-grey clay	6	0	1,108	0
157	Limestone ...	1	0	1,109	0
158	Marl	1	0	1,110	0
159	Limestone ...	1	0	1,111	0
160	Marl	1	0	1,112	0
161	Sandstone ...	1	0	1,113	0
	Coal-measures—				
162	Shale	11	6	1,124	6
163	Sandstone ...	1	0	1,125	6
164	Bind	11	0	1,136	6
165	COAL	1	3	1,137	9
166	Sandstone parting	1	0	1,138	9
167	COAL	1	3	1,140	0
168	Clay with *coal*-streaks	7	6	1,147	6
169	Sandstone ...	3	6	1,151	0
170	Shale with a little *coal*	6	6	1,157	6
171	Sandstone with *coal*-streaks ...	42	0	1,199	6
172	COAL	0	6	1,200	0
173	Sandstone with *coal*-streaks ...	29	0	1,229	0
174	COAL	2	0	1,231	0
175	Underclay ...	1	6	1,232	6
176	Shale, level bedded	16	0	1,248	6
177	Bind	28	6	1,277	0
178	COAL	2	0	1,279	0
179	Bind	21	0	1,300	0
180	Sandstone ...	11	9	1,311	9
181	COAL	1	3	1,313	0
182	Shale	1	6	1,314	6
183	Dark grey stony bind	47	0	1,361	6
184	Sandstone ...	4	6	1,366	0
185	Strong dark grey bind with thin bands of sandstone	38	0	1,404	0
186	Blue bind... ...	12	0	1,416	0
187	Dark grey bind ...	11	0	1,427	0
188	Fire-clay with some *coal* ...	1	0	1,428	0
189	Hard fire-clay ...	5	0	1,433	0
190	COAL	1	0	1,434	0
191	Dark grey sandstone with *coal*-marks	7	6	1,441	0

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Bottom of Shaft. Ft.	In.
192	Dark shaly bind	15	0	1,456	0
193	**COAL**	2	6	1,458	6
194	Fire-clay and bind	8	6	1,467	0
195	Dark stony bind...	5	0	1,472	0
196	Blackish-grey sandstone	12	0	1,484	0
197	Dark grey jointed sandstone with *coal*-streaks ...	29	0	1,513	0
198	Bind, level-bedded	2	0	1,515	0
199	Sandstone, with *coal*-streaks ...	16	0	1,531	0
200	Dark grey jointed grit	5	0	1,536	0
201	Hard grey sandstone with *coal*-streaks... ...	13	0	1,549	0
202	**COAL**	0	4	1,549	4
203	Dark grey bind ...	2	2	1,551	6
204	Sandstone ...	3	6	1,555	0
205	Bind	4	0	1,559	0
206	Strong dark grey bind	11	0	1,570	0
207	**COAL**	2	3	1,572	3
208	Bind	4	9	1,577	0
209	Hard grey sandstone with some *coal*-streaks ...	30	0	1,607	0
210	Bind	2	0	1,609	0
211	Hard grey jointed sandstone with *coal*-streaks ..	64	0	1,673	0
212	Coarse grey grit with *coal*-streaks	8	0	1,681	0
213	Hard grey jointed sandstone with *coal*-streaks ...	48	0	1,729	0
214	Dark grey stony bind	10	6	1,739	6
215	Hard grey jointed sandstone, level bedded, with *coal*-streaks ...	24	3	1,763	9
216	**COAL**	2	9	1,766	6
217	Hard dark underclay	5	6	1,772	0
218	Hard fine-grained jointed sandstone	11	0	1,783	0
219	Dark grey bind, with clay partings	12	0	1,795	0
220	Dark sandstone and bind ...	4	0	1,799	0
221	Dark grey silty, grained, foliated sandstone, with *coal*-stained interbedded leaves, fairly level bedded	32	0	1,831	0
222	**COAL**	1	8	1,832	0
223	Hard underclay ...	3	4	1,836	0
224	Dark grey, fine-grained sandstone	5	0	1,841	0
225	Strong dark grey jointed bind ...	10	0	1,851	0
226	Dark grey clay ...	2	0	1,853	0
227	Shale, bind and clay, with streaks of *coal*	2	0	1,855	0
228	Dark jointed shaly bind	3	0	1,858	0
229	Strong dark bind	2	0	1,860	0
230	Dark grey sandstone, with *coal*-streaks and plant impressions ...	7	0	1,867	0
231	Hard grey sandstone	5	0	1,872	0
232	Dark grey hard sandstone, with *coal*-specks and a few *coal*-streaks	14	0	1,886	0
233	Hard grey sandstone	9	0	1,895	0
234	Dark grey sandstone, with *coal*-streaks... ...	6	0	1,901	0
235	Coarse grey sandstone, with *coal*-streaks... ...	17	0	1,918	0
236	Grey sandstone, with *coal*-specks	7	0	1,925	0
237	Sandy bind ...	3	0	1,928	0
238	Hard grey sandstone, with *coal*-streaks... ...	15	0	1,943	0
239	Hard grey grit ...	2	0	1,945	0
240	Hard grey sandstone, with *coal*-streaks... ...	17	0	1,962	0
241	Hard jointed grey sandstone, with *coal*-streaks and plant impressions	21	0	1,983	0
242	Dark grey bind, with plant impressions ...	3	0	1,986	0
243	Strong dark grey clay, with plant impressions ...	14	0	2,000	0
244	Dark grey jointed sandstone ...	5	0	2,005	0
245	Dark grey sandy bind	4	0	2,009	0
246	Hard blackish fireclay	4	0	2,013	0
247	Sandy bind ...	1	0	2,014	0
248	Fine grey sandstone	2	0	2,016	0
249	Strong dark grey bind, level bedded, with plant impressions ...	22	0	2,038	0

No.	Description of Strata.	Thickness of Strata. Ft.	In	Depth from Bottom of Shaft. Ft.	In.
250	**COAL**	1	0	2,039	0
251	Hard dark grey fire-clay ...	8	0	2,047	0
252	Blackish shale, level bedded, with some *coal* and plant impressions ...	3	0	2,050	0
253	Clay bind, with plant impressions	4	0	2,054	0
254	Sandy bind ...	4	0	2,058	0
255	Coarse grey sandstone, with *coal*-streaks	27	0	2,085	0
256	Dark grey grit, level bedded, with *coal*-streaks and partings ...	20	0	2,105	0
257	Hard grey sandstone, with *coal*-streaks	14	0	2,119	0
258	Blue bind... ...	5	0	2,124	0
259	Sandy bind ...	2	0	2,126	0
260	Blue bind... ...	2	0	2,128	0
261	Fine sandstone ...	7	0	2,135	0

APPENDIX B.—THE FOSSIL IMPRINT COAL-BORING.

By R. Zeiller,

*Engineer-in-Chief of Mines; Lecturer on Vegetable Mines, Paris.**

It is generally known that the boring undertak Tunnel Company, at the suggestion and under the di engineer of that company, has reached the Coal-mea (352 mètres), and it has met in a total depth of 1,930 coal, eight of which are more than one foot in thick exactly horizontal, which leads Mr. Brady to conc have been struck in the central part of the basin.

The coal found in the seams contains, according Watteyne, *Ingénieur principal des Mines* of Belgiu matters, and partly resembles in composition the *c* Calais, and partly those of Wales. In spite of the structure between some of the sandstones met with in lowest region of the Coal-measures of Belgium, Mr. W the Dover coals belong to the base of the formation, on a of volatile matters, and Mr. Brady for his part sees in boring the equivalent of all or most of the coals belong the Somerset basin; that is to say, the beds of Farring

* *Comptes rendus des Académie des Sciences*, Paris, 1

As, however, the quality of a coal in volatile matters does not constitute an absolute criterion for the determination of the level, these opinions could not, without more ample information, be accepted except with reserve; but it was permitted to hope that amongst the vegetable imprints collected in the course of the boring operations specimens would be met with susceptible of furnishing more precise indications on this important question.

These imprints having been sent to me, thanks to Mr. L. Breton, *Ingénieur Directeur* of the Tunnel company's works at Calais, and to the kindness of Mr. Brady, the writer has been able to recognize amongst them some ferns which only appear between well-determined levels of the Coal-measures, and which are consequently of a nature to solve the problem, or, at least, to confine the solution to extremely narrow limits.

The levels where these imprints are found are those of 1,894 feet (577 mètres) below the surface of the ground, 1,900 feet (579 mètres) and 2,038 feet (621 mètres). The boring is still progressing and has actually attained, according to Mr. Brady, a depth of 2,100 feet (640 mètres) from the surface. The writer has recognized the following species:—

From the level of 1,894 feet:—A fragment of fern-frond with dentated pinnulas and nervation approaching the type *Odontopteris*, which the writer is disposed to rank in the genus *Mariopteris*, and which resembles in a notable degree the *Mariopteris sphenopteroides* Lesq., without being able to positively assign it to this species. The specimen is, indeed, too incomplete to be susceptible of a precise determination.

Neuropteris Scheuchzeri Hoffm., represented by large detached pinnulas.

Neuropteris rarinervis Bunb.; fragments of fronds well characterized.

Neuropteris tenuifolia Schloth.; portions of fronds.

Lepidodendron aculeatum Sternb.; ramule identical with certain specimens of the Valenciennes basin, besides numerous heart-shaped grains (*Cordaicarpus*) of 0·195 to 0·234 inch (5 to 6 millimètres) in height by an equal width, very analogous to *Cord. congruens* Grand' Eury, but with a striated surface. The writer would be disposed to assign them to *Carpolithes corculum* Sternb.

From the level of 1,900 feet:—*Neuropteris Scheuchzeri. Neuropteris rarinervis. Neuropteris tenuifolia; Cyclopteris*, a fragment; *Calamophyllites Gœpperti*, Ettingsh.: a portion of stem articulated with cicatrices of leaves, easily recognizable; *Lepidostrobus variabilis* Lindl. and Hutt; *Cordaicarpus* cf. *corculum* Sternb.

From the level of 2,038 feet:—*Neuropteris Scheuchzeri:* a fragment of pinnula, a little uncertain; *Lepidodendron lycopodioides* Sternb.: a fragment of branch, rather badly preserved; *Stigmaria ficoides* Sternb.

All these species indicate the Coal-measures, but the greater part do not permit of a more precise reference. Indeed, the *Calamophyllites*, *Lepidodendron Lepidostrobus*, *Stigmaria* that the writer has just cited, are found indifferently in nearly the whole thickness of the Middle Coal-measures and in a part, at least, of the upper stratum. The *Neuropteris tenuifolia* is especially common in the Valenciennes basin in the most elevated zone, that of the *charbons gras* and *flénus* of the Pas-de-Calais; yet it is observed, although rarely, at the base of the middle zone of the same basin; it will not serve, therefore, as a basis for the determination of level.

It is not the same, fortunately, with the *Neuropteris rarinervis* and *Neuropteris Scheuchzeri;* these, indeed, have only been observed, in America as well as in Europe, towards the top of the Middle Coal-measures or at the extreme base of

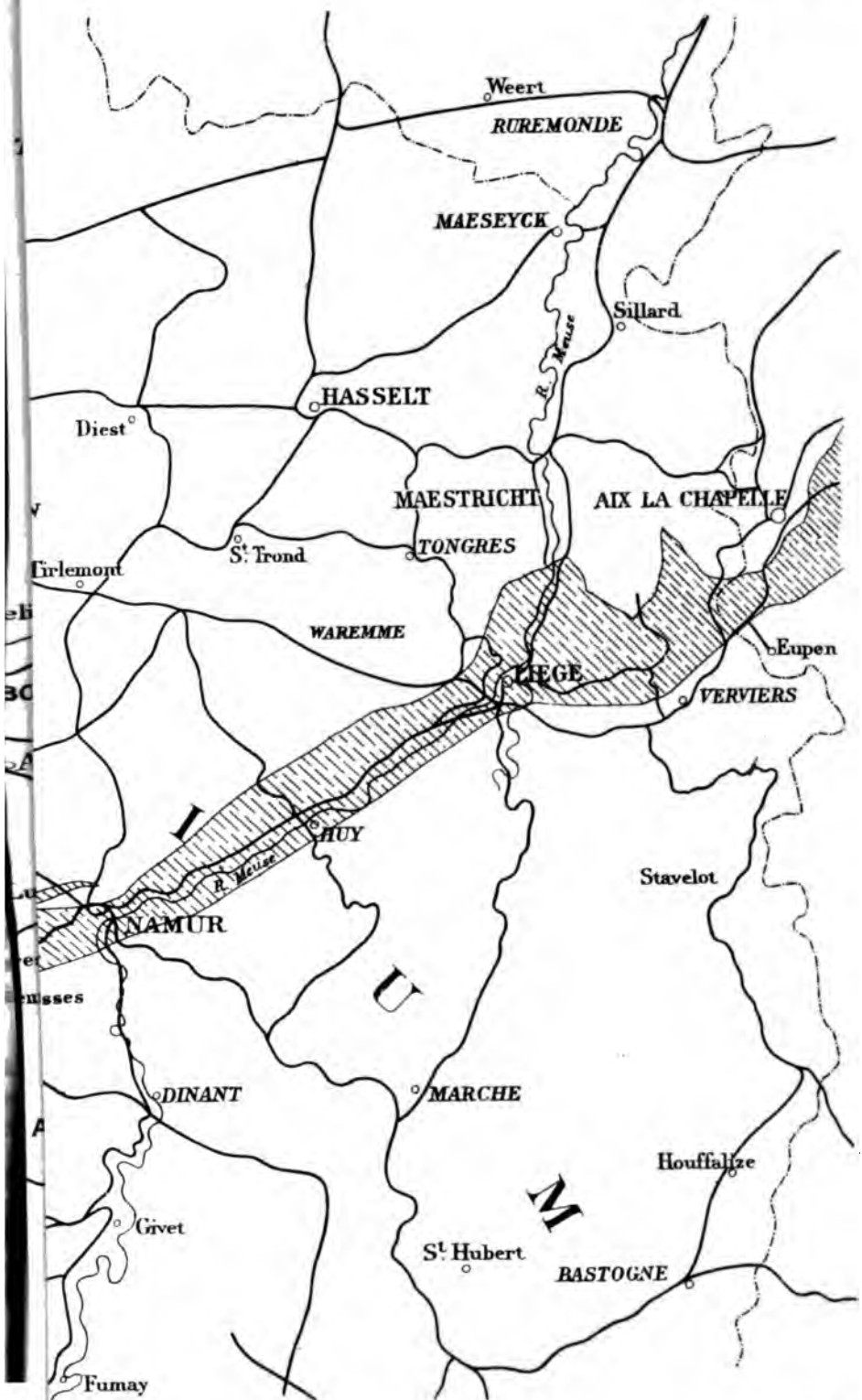
measures. In Staffordshire the levels at which they have been met Middle and Upper Coal-measures correspond with the upper zone o Calais and the zone, a little more elevated, of Farrington and Radst

It may, therefore, be concluded from the presence of these two s Dover boring, that, as presumed by Mr. Brady, the beds traversed b rightly belong to the upper region of the Middle Coal-measures, an state it more precisely, that they cannot be either more recent tha Radstock in Somerset or more ancient than the deepest beds of t (*charbons gras et flénus*) of the Pas-de-Calais.

Mr. Joseph Dickinson said that he was glad that the a paper had referred to the names of Mr. Godwin Austen and Prestwich. Sir Joseph Prestwich's section laid down the line field to almost a hair's-breadth, and the depth was indicated al as proved. Prof. W. Boyd Dawkins, whose name was not r the paper, had done so much in enlightening members on that they should not pass it over without mentioning his nam

Mr. N. R. Griffith said he must apologize for the omiss Boyd Dawkins' name. The omission was entirely his fault, as pared the paper from material supplied by Mr. Brady. The recommenced last week, it was then about 82 feet, and they about 3 feet a day.

The President said he could only wish success to the com had taken up such an important position. From all they had


Weert
RUREMONDE
MAESEYCK
Sillard
R. Meuse
HASSELT
Diest
MAESTRICHT
AIX LA CHAPELLE
TONGRES
St. Trond
Tirlemont
WAREMME
Eupen
LIEGE
VERVIERS
HUY
R. Meuse
Stavelot
NAMUR
DINANT
MARCHE
Houffalize
Givet
St. Hubert
BASTOGNE
Fumay

Mr. N. R. GRIFFITH said that, so far as he knew, no determination had been made of the verticality of the bore. He had not attempted to make any estimate of this addition to their coal resources, but it had an important national bearing: assuming that the coal-field was 50 miles in length, 4 miles in width, and the coal only 18 feet thick, it would supply 30 millions of tons of fuel a year for the next 100 years.

The PRESIDENT moved a vote of thanks to the writers of the paper, and it was cordially adopted.

DISCUSSION UPON THE "REPORT OF THE PROCEEDINGS OF THE EXPLOSIVES COMMITTEE."*

Mr. JAMES DARLINGTON asked how many experiments were tried when an ignition took place; for instance, carbonite and coal-dust in suspension fired in the first instance—were any further experiments made, and was there a further ignition of dust?

Mr. A. C. KAYLL said that the committee decided upon a certain given number of experiments to be made in any series—say forty. When the explosive ignited, the remainder of the experiments of that series were discontinued. In the case of carbonite, it ignited at the first shot, and it was discarded, having been found capable of igniting coal-dust.

The following "Notes on the Geological Features of the Coast of North Wales," by Mr. C. E. de Rance, were taken as read:—

* *Trans. Fed. Inst.*, vol. viii., pages 227 and 593; vol. ix., pages 115, 206, and 274; vol. x., pages 38, 197, 492, and 503; and vol. xi., pages 175 and 218.

NOTES ON THE GEOLOGICAL FEATURES OF THE COAST OF NORTH WALES FROM LIVERPOOL TO MENAI BRIDGE.

By C. E. De RANCE, Assoc. Inst. C.E., F.G.S., of H.M. Geological Survey.

"Railway Geology" has passed into a well-known phrase, but as regards "Steamer Geology"* on the sea, the connexion seems less obvious, but it occurs to the writer that much of interest to the geologist may be observed in the expedition by sea from Liverpool to Menai Bridge.

First, if the scenery visible be analysed and compared, it will be realized how false are the popular notions of the comparative stability of land and water; the phrases "unstable as water" and "the everlasting hills" being equally contrary to the geological continuity that has resulted in the present position of the Irish Sea, and the three great land-masses seen on leaving Liverpool, viz., the mountains of the Lake District to the north terminating with an apparently conical mountain called Black Coombe, the Pennine chain forming the backbone of England to the east, and the North Wales mountains culminating with Snowdon's peak to the south-west, while, in favourable conditions of the atmosphere, the Isle of Man and Anglesey rise to a less height on the far-off horizon.

The floor of land and sea has for its foundation the Archæan rocks, some of the oldest in the world: these are seen near Bangor station, and consist of greenish slates and hornstone, and are overlain, as Prof. McKenny Hughes has pointed out, by the basement-conglomerate of the Lower Cambrian in the road near the entrance to the recreation ground, which is situated on the overlying Cambrian purple and green mudstones and slates. The Archæan beds referred to overlie micaceous and chloritic schists, traversed by granite-veins and masses; these are well seen near Beaumaris, but also occur near Bangor, and with the overlying hornstones, etc., form the Bangor Beds of Prof. McKenny Hughes, being the Upper Pebidian of Dr. Hicks.

The Cambrian rocks are not less than 35,000 feet thick in North Wales, they contain the celebrated Llanberis Slates, which have been worked as early as the twelfth century, the Penrhyn quarries being no less than 500 feet in depth; the planes of division are true cleavage induced by pressure, whilst the dip of the measures is only obscurely shown by the green stripe on the face of the purple slate. Occasionally

* These notes were written (at the request of the secretary) to illustrate an excursion of the members of the Institute from Liverpool to Menai Bridge.

these are found to be beautifully rippled by the action of currents, whether of wind or water is somewhat uncertain, no fossils having been as yet discovered in them, save a few traces of marine worms: now and then the stripe is found to be faulted a few inches, and these are sometimes reversed faults, which invariably are found to be "faulted faults," as probably are those occurring in other strata and on a larger scale.

Above these rocks occur the *Lingula* Flags, which are seen near Bangor, and further south contain gold veins. In the Cambrian period marine shells point to marine conditions, sand and mud, sun-cracks and raindrops (fossilized) to the sea being shallow. The sediments were derived from old land to the north, where the Irish Sea now is, volcanic activity increased, and volcanoes existed, rivalling Etna in height, from which ashes were blown by the westerly winds towards the east. The overlying Bala or Caradoc beds mainly form the mountain-masses of Snowdon, Carnedd-Llewelyn, and others of the wildest and grandest in North Wales, and often they are the roots of old volcanoes which have been uplifted to their present height long after they ceased to be in active operation.

In the Lake District, the Cambrian and Lower Silurian rocks occur, with slates less perfectly cleaved, the oldest rock being the Skiddaw Slates, which form the mass of Black Coombe, the westernmost visible mountain in the Lake District panorama as seen from the south. The Archæan rocks have not been identified, and the Cambrians in this area are the oldest; the Bala Beds of North Wales have the same group of fossils as the Coniston Series of the Lake District, and there can be no doubt that in Cambrian times the sea extended across the Irish Sea to the whole of the Cumbrian area and into Scotland.

In Flintshire, the slope fringing the estuary of the river Dee consists of Middle Coal-measures, overlying cherts of Millstone Grit age, resting on the Carboniferous Limestone, forming a well marked headland at Prestatyn, and runs up both sides of the Vale of Clwyd.

In Denbighshire, the hills forming the sky-line from the entrance of the Vale of Clwyd to that of the Vale of Conway consist of Silurian Denbighshire Grits. These are overlain by the Carboniferous Limestone, which forms a second parallel terrace nearer the sea, and is well seen from Abergele to Penmæn Rhos. The limestone forms fine outliers, such as Penmæn Rhos, the Great Ormes, and Little Ormes Head. The copper ore anciently worked at Llandudno occurred at the base of the limestone at its junction with the Silurian floor beneath.

Manganese and hæmatite occur in a conglomerate-bed in several places at the base of the limestone; the ore appears to be a pseudomorph after

a calcareous setting of the pebbles, which consist of a pale green Silurian sandstone; many of these occur on the beach at Abergele, being brought by underground streams through the hills. On clear days the entrance to the caves there can be seen at a considerable distance from the land.

In Anglesey, faults have preserved a patch of Carboniferous Limestone and some true Coal-measures; the latter reach 1,309 feet in thickness, with seven coal-seams (one being 9 feet in thickness); 200 feet of yellow sandstone and conglomerate (Millstone Grit) lies beneath, and then comes 450 feet of Carboniferous Limestone. The beds are thrown in by a fault of 203 feet; it extends from Hirdre-faig to Malldraeth Bay.

Looking eastward, from Liverpool bay, the Pennine hills rise to more than 2,000 feet, and consist of Carboniferous strata, newer than the Mountain Limestone, of no less than 8,000 feet in thickness, while the Coal-measures above them attain the same thickness. It is worthy of note that when the Carboniferous Limestone was deposited in a sea which stretched from Anglesey to Grange and beyond, not one foot of the 16,000 feet of Upper Carboniferous strata had been deposited in Lancashire: it is probable that land, estuaries, and lagoons covered the whole of the area lying between the Anglesey and Lancashire coal-fields, and from what the writer has seen of the Whitehaven and Kilkenny coal-fields, there is little doubt that they were more or less continuous, though it is improbable that individual coal-seams extended far.

The slopes between the Pennine hills and the coast-margin of Lancashire consist of the Triassic rocks, which in this county and that of Chester, here reach their maximum amount of sedimentation, being nearly 5,000 feet thick. These rocks do not occur in North Wales, except in the Vale of Clywd, where they overlie a concealed coal-field, proved by a deep boring at Rhyl, but it is probable that the more productive part lies under the sea, north of that town.

It is worthy of note that, except at Heysham Point, near Morecambe, where the Midland Railway have just obtained powers to make a new port, rock of any age never forms the coast-line, which is either blown sand raised by the wind into dunes, or glacial drift deposits, formed during the passage of an ice-sheet, entirely filling up the whole of the Irish Sea, as far as Anglesey. The Cheshire coast of Wirral also, except at the "Red Noses," at the mouth of the Mersey, is entirely composed of drift. The sandhills at Leasowe lighthouse and westward to the Dee at West Kirby are underlain by peat, resting on a grey clay; trees, with their roots implanted, which occur beneath these, are seen extending out to

low water, and at Birkdale (Lancashire) they have been proved to occur 70 feet below high-water mark; when the present sea-bottom was land and trees grew on it, there was a communication with the Isle of Man and Cumberland, and this at a period since man's advent into Lancashire. On the other hand, the old valleys of the rivers Dee and Weaver have been proved by borings to have been 200 feet higher above sea-level, at the period before the ice-sheet overspread the Irish Sea, than they are at present. Whether the weight of the ice-sheet caused the depression is a matter of interest; at any rate all the facts adduced from the long vista of the past point to a succession of oscillations in level.

The PRESIDENT moved that a hearty vote of thanks be accorded to the owners of works opened to the inspection of the members during the course of the meeting, to the Coal-owners of South-west Lancashire, to the Governors of the Mining School for their kindness in allowing the use of the school for the meeting, and to Mr. Henry Hall and Mr. John Knowles for the trouble that they had taken in making the arrangements requisite for the meeting.

Mr. JOSEPH DICKINSON proposed a vote of thanks to the President for his services in the chair, which was cordially agreed to.

The following notes record some of the features of interest seen by the visitors to collieries, which were, by kind permission of the owners, open for inspection during the course of the meeting on July 14th, 15th, and 16th, 1896 :—

PARK COLLIERIES.

The No. 1 pit is 13 feet in diameter and 135 feet deep to the Wigan 9 feet mine; the Wigan 4 feet mine is also worked at this pit The horizontal winding-engine has two cylinders, each 16 inches in diameter and 3 feet stroke, and is fitted with a drum 7 feet in diameter. The haulage is on the endless-rope system, worked by an engine placed aboveground. At the bottom of this pit is a double-acting pump (5 inches in diameter) which supplies the water to the slack-washer. The coal is passed over fixed screen-bars, and is picked on travelling-belts made of steel-plates.

The No. 2 pit is 14½ feet in diameter and 954 feet deep to the Arley mine; the Orrell 5 feet or Rushy Park seam is also worked. The horizontal winding-engine has 2 cylinders each 26 inches in diameter and 4½ feet stroke, and is fitted with a drum 16 feet in diameter. The haulage is on the endless-rope system, and is worked by a hauling-engine on the surface. The coal is screened by "shakers," which separate the coal from each mine into three sizes.

The No. 3 pit is the upcast shaft for Nos. 1 and 2 pits; it is 14½ feet in diameter and 954 feet deep. The horizontal winding-engine has 2 cylinders, each 18 inches in diameter and 3 feet stroke, and is fitted with a drum 8 feet in diameter.

The mine is ventilated by a Walker fan, 24 feet in diameter, fitted with the Λ-shutter. The fan is driven by a horizontal compound condensing engine: the high-pressure cylinder is 22 inches in diameter, the low-pressure cylinder 38 inches in diameter and 4 feet stroke. A pulley, 16 feet in diameter, on the engine-shaft transmits the power by 15 cotton ropes to a pulley 7 feet in diameter on the shaft of the fan. A Hall ventilation-recorder is placed in the manager's office, and is connected with the fan-drift. The fan is capable of passing 300,000 cubic feet of air per minute at a water-gauge of 6 inches.

The hauling-engine is compound and condensing, with a high-pressure cylinder 20 inches in diameter and a low-pressure cylinder 36 inches in diameter and 4 feet stroke. The two haulage-ropes are carried on taper-tread pulleys on the third-motion shaft, which is geared down as 7 to 1. The rope-pulleys are fitted with clutch arrangements, so that either rope can be thrown in or out of gear as required. Both ropes pass down the No. 3 pit.

In the boiler-house are four Lancashire boilers, each 30 feet long and 8 feet in diameter, blowing-off steam at a pressure of 100 lbs. per square

inch. At the back of the boiler-house is a Green economizer containing 256 pipes.

The slack-washer is of the trough-type, and has a capacity of about 200 tons per day.

There are carpenters' shops, wagon-painting and repairing shop, smithy with a small steam hammer, stables, etc.

About 800 safety-lamps of the Marsaut type are in use.

MOSS HALL COAL CO., LIMITED, MAYPOLE SINKING.

The Maypole sinking of the Moss Hall Coal Company, Limited, is a new winning and extension of their present coal-field in a southerly direction beyond a fault of 540 feet, the boundary of their present workings. This fault throws 480 feet of red sandstone into the present sinking-shafts.

The works were commenced about fifteen months ago. They consist of a brickworks with drying-sheds, kilns, and a plant capable of making 12,000 pressed bricks per day.

The No. 1 pit is sunk down and bricked to a depth of about 400 feet, and has about 90 feet further to go before it passes through the red rock.

At the present time 60,000 gallons of water per hour is being pumped by a Hathorn-Davey pumping engine of the bull type, with a steam cylinder 70 inches in diameter and 8 feet stroke and beam underneath. Coupled to this is a ram 24 inches in diameter and 10 feet stroke, with a steel rising-main 20 inches in diameter. There are two sets of spears, a spare set to be coupled up to another ram to pump to the present ram when the water-bearing strata are passed through. The present ram is pumping out of lodges at a depth of 348 feet.

A Pearn pump is fixed at a depth of 348 feet with two steam cylinders 24 inches in diameter and rams 10 inches in diameter and 18 inches stroke.

Two Evans Cornish sinking-pumps are slung from the surface; they have steam cylinders 24 inches in diameter and rams 12 inches in diameter and 24 inches stroke. The slings consist of steel rods 3½ inches in diameter in 10 feet lengths, raised or lowered with a screw 5½ inches in diameter worked by two pairs of self-contained engines with steam cylinders 10 inches in diameter and 9 inches stroke, and all the connexions are put on at the surface. The sinking to the present depth has been done with the sling-pumps dealing with the water.

The winding-engine for sinking this pit has two steam cylinders 24 inches in diameter fitted with Cornish valves and a drum 10 feet in diameter; they are geared $3\frac{1}{2}$ to 1, and Elliott locked-coil ropes are in use.

The No. 2 pit, 126 feet deep, is standing at present; it was sunk to this depth with a self-contained Dunlop engine. The permanent winding engine has two steam cylinders, each 33 inches in diameter and 6 feet stroke, fitted with Cornish valves; the drum is 15 feet in diameter. The further sinking of this shaft will be effected with these engines.

There are six double-flued Lancashire boilers, each 30 feet long and 8 feet in diameter, working at a pressure of 100 pounds per square inch.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, JULY 13TH, 1896.

MR. E. B. WAIN, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

DISCUSSION ON DR. J. HALDANE'S PAPER ON "THE CAUSES OF DEATH IN COLLIERY EXPLOSIONS."*

The PRESIDENT observed that, although the paper was a technical one to a great extent, Dr. Haldane gave good advice; and no doubt as time went on, seeing that he was working with some of the best mining engineers in the country, they would find his theory put into practice, and saving of human life would result from his researches. Dr. Haldane had communicated several papers to The Federated Institution of Mining Engineers, and was not afraid to make experiments even on himself, as he had done at Lilleshall colliery, in order to test the atmosphere and ascertain how much carbon monoxide a man could stand. Dr. Haldane found that it was practically safe to remain a long time in an atmosphere that would not support combustion. The old idea that when a candle went out it was not safe for a man to be in the atmosphere was disproved by Dr. Haldane's experiments.

Mr. C. E. DE RANCE said that one circumstance occurred to him while hearing the reading of Dr. Haldane's able paper, and it had reference to the Severn tunnel. The Severn tunnel was 4½ miles long and passed through a variety of strata, 2¼ miles of which are under the tide-way, and when it reached the Welsh shore it encountered beds of Pennant grit, heavily charged with water, which were expected to be a point of danger. To meet that danger iron doors had been put in to shut off the water. The springs suddenly came in before the doors could be shut, and the question was how the water could be dealt with, without these doors being shut. Mr. Fleuss was consulted and one of his assistants in a diving-dress, with an oxygen cylinder on his back, undertook to go down. He had to grope his way under water, find the iron doors, and shut them. The doors were shut, the water

* *Trans. Fed. Inst.*, vol. xi., page 502.

was eventually pumped out, the springs which yielded 5,000 gallons a minute were made watertight, and trains are now running through the tunnel every day with perfect safety.

It appeared that carbon monoxide was largely the cause of deaths in an explosion in a mine; and he gathered from the paper which had been read, that if oxygen was applied soon enough the danger might be remedied. Looking at the wonderful experience of Mr. Fleuss' assistant—if several men had similar apparatus, they might not only be able to enter the workings, but get the disabled men out of the mine in time for medical men to administer proper remedies for their sufferings.*

Mr. W. BAILES said after the Seaham explosion it was found in some cases that death had taken place almost instantly. Men had evidently rushed for their lamps, turned round and fallen with the lamps in their hands, so that in the first instance they had some warning before the carbon monoxide killed them. With reference to the air-crossings and stoppings being made fast, he was afraid that would work both ways. He was one of the first volunteers to explore after the Seaham explosion, and when they got to the men at the pit-bottom, they gathered from the men that some of the stronger and fleeter had come away and left others behind. Between the pit-bottom and those men there was an air-crossing, but those men who were got out alive had to pass the bodies of the others. One of the men found dead had fallen on his lamp and the lamp had burnt him. In another case, where the force of the explosion had passed, they found a man who was not burnt. Evidently the violence of the current had been imparted to the air and thrown him over. In other cases it was evident that men had died from the effects of gas after the explosion, because there was a pink ooze from the eyes, ears, and nose. With respect to the after-damp making its way into the workings beyond, they had clear proof that the after-damp did find its way into the workings; men had met it, but they were driven back to the face, and after making several attempts to get out of it, they wrote on a board a description of the condition that they were in and lay down to die. Another man was found in a return air-way, where he had dropped on his knees and died. In another case a considerable number of

* "Fleuss Apparatus for Breathing in Noxious Gases," by Mr. T. W. Bunning, *Trans. N.E. Inst.*, 1882, vol. xxxi., page 197. "New Exploring Respirator (Forster and Fleuss)," by Mr. J. S. Martin, *Trans. Manc. Geo. Soc.*, 1880, vol. xvi., page 259. "Respirators and Lamps for Penetrating Noxious Gases," by Mr. Joseph Dickinson, *Ibid.*, 1882, vol. xvii., page 95. "Fleuss Breathing Apparatus and Lamp," by Mr. Brown, *Ibid.*, vol. xvii., page 131.

men had come to a fall, and the air had been good till they reached that place, for they had wrapped up their jackets and used them as pillows, and were afterwards poisoned as they lay there. In his experience in opening out it was evident that at the extreme end of the working-face the air remained fresh for a considerable period. Whether it would have continued so if the men had not come out from the face, he was not able to say, because the natural course was for every one to make for the shaft. Unless persons were certain that the air would remain pure at the working-face they would not stop at the inbye end.

Mr. Wm. Heath said that there would be great difficulty in persuading men, on all occasions where there were explosions, to be discreet in what they were doing. They had not time to think, and generally rushed to the shaft for safety. However, they must be thankful to Dr. Haldane, to whom great credit was due for the manner in which he had brought the matter before the members. He moved a vote of thanks to Dr. Haldane for his valuable paper.

Mr. T. E. Storey seconded the motion, which was cordially approved.

DISCUSSION ON MR. C. E. DE RANCE'S PAPER ON "THE DEPTH TO PRODUCTIVE COAL-MEASURES BETWEEN THE WARWICKSHIRE AND LANCASHIRE COAL-FIELDS."*

Mr. de Rance said that the paper which he read at Shelton had since formed one of a group of papers by Prof. Hull and Mr. Coke in reference to the geology of the Midland district. It was always an interesting subject to him (Mr. de Rance), and he had pleasure in saying from all he had since seen, and from the results of borings given to him recently by Mr. Webb, of the London and North-Western Railway, and others, that he was strengthened in the views which he had expressed in his paper. As regards, for instance, the Red Rocks which occurred below the New Red Sandstone and above the Upper Coal-measures of Lancashire, he had just been drawing up two plates of vertical sections of the Permian rocks, obtained in borings between Liverpool and Manchester, for the purpose of publication by H.M. Geological Survey. They showed extraordinary variability of thickness, a variability in the case of the true Permians, of no less than 1,000 feet in vertical thickness in 1½ miles. So that if the question was put before him as to the depth, in that area, to productive Coal-measures, the old Cornish rule would apply "where it is, there it is," and

* *Trans. Fed. Inst.*, vol. x., page 244; and vol. xi., page 21.

each locality must be taken on its merits. When the facts were examined it was found that the fossiliferous (Zechstein) Permian, corresponding to that found in Russia, never occurred in the Midland counties. It was gone when they got south of the Stockport Permian rocks (containing Zechstein fossils, identified by Dr. Geinitz as the same as those occurring in Russia); the type there ceased, and directly they crossed the middle plain of Cheshire they lost these measures entirely, and what was called "Permian" in North Staffordshire or Warwickshire was older than the Zechstein Permian, if it belonged at all to that formation. The New Red Sandstone might be compared to a wedge, the thick part of which rested on Cheshire, the thin end on Oxford being only 400 feet thick at Burford in Oxfordshire. Cheshire had the maximum thickness of Triassic rocks in the British Isles. He knew with respect to the Keuper the maximum records for some years, but since that time it had been proved near Liverpool that the Pebble Beds of the Bunter were 2,300 feet thick, and they had not yet got to the bottom. The New Red Sandstone maximum development in Cheshire precluded coal from being commercially worked. But in Warwickshire the Bunter is absent, the Keuper thin, and unconformably overlies the so-called Permian measures, which always conformably overlies the Coal-measures beneath. The Zechsteins of Lancashire were just the reverse, at Bedford Leigh they rested on the highest Coal-measures, while near Ormskirk they were resting on the Millstone Grit, though only about 9 miles distant. Whatever the age of such Red Beds, as were older than the Zechstein might be, they were clearly associated with the uppermost Coal-measures. This was proved by the borings made for the Coventry Corporation, the Hamstead colliery, near Great Barr, and the boring recently made at Trentham. The so-called Permians, and all the Red Rocks of the Coal-measures, had been tilted and denuded before the Triassic rocks were deposited. When they came to Cocknage, near Longton, the Pebble Beds of the New Red Sandstone laid on the Upper Coal-measures, and a little farther south the Upper Coal-measures were gone. Going a little further to the north in the Adderley Green district the Pebble Beds rested upon the Middle Coal-measures with a southerly dip, and still farther north, at Endon, the Pebble Beds rested directly on the Yoredale rocks. In South Warwickshire they found none of the Bunter or Lower Keuper Basement Beds. When they went to the Mendip Hills the Keuper marl overlapped everything, transgressively passing over older and older rocks, till it rested upon the Carboniferous Limestone of the Mendip Hills.

The meeting then closed.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, APRIL 16TH, 1896.

MR. J. H. COOKSEY IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. GEORGE C. ROBINSON, Mining Engineer, Brereton.
Mr. F. W. BRAIN, Civil Engineer, Drybrook, Gloucester.
Mr. DAN MORGAN, Colliery Manager, Bath.
Mr. REGINALD THOMAS, Assistant Manager, Rugeley.
Mr. WILLIAM HALL, Under-manager, Pelsall.

TECHNICAL EDUCATION.

The SECRETARY reported that the Staffordshire County Council had decided to offer two scholarships, each of the value of £30, and at the discretion of the committee, maintenance allowance, available for students attending the local mining classes, and tenable at Mason College or some other suitable institution.

Mr. ROBERT S. WILLIAMSON read the following paper on "Underground Haulage at Cannock and Rugeley Collieries":—

UNDERGROUND HAULAGE AT CANNOCK AND RUGELEY COLLIERIES.

By ROBERT S. WILLIAMSON.

The question of underground haulage of coal, forming as it does such an important factor in colliery management, must be the writer's excuse for reading this paper. The various kinds of mechanical haulage are generally well known. It is not the intention of the writer to advocate the superiority of any one system over another, but simply to place before the members those applied at the collieries under his charge. Each year the necessity of having efficient and economical haulage, with a view of reducing working costs to the lowest possible point, becomes more important.

The systems used are main-and-tail rope, endless rope, by power, and endless rope on self-acting inclines, etc. The powers used are steam, compressed air, and electricity.

The writer may mention that the whole of the coal drawn at the different pits is brought to the pit-bottoms by rope-haulage, and that the output of the various plants is equal to 3,000 tons in an eight hours' day.

Cannock Wood Mine.

Shallow Coal-seam (*Fig. 1, Plate XXX.*).—The far station in the south-east district is situated at a distance of 5,790 feet from the shaft-bottom. The haulage is effected by main-and-tail rope. The engine has one horizontal cylinder, 32 inches in diameter by 5 feet stroke, and is fitted with two drums, 4 feet in diameter, worked by friction-gear, the proportion being as 1½ to 1. This engine, a disused winding-engine, in addition to hauling, works an air-compressor (20 inches in diameter), which supplies air for hauling-engines and heading-machines. The ropes are conveyed down the shaft in boxes.

The remaining western districts in this seam are worked by endless rope, the power being derived from electricity. A short description of this plant was recently given by the writer to the members.* Consider-

* *Trans. Fed. Inst.*, vol. iii., page 483.

able extensions have taken place since that paper was written. The rope has been extended 2,580 feet to the north-west; the far station is 160 feet below the shaft-bottom, and the gradient against the load varies from 1 in 6 to 1 in 8. The tubs in coming up the incline are run singly; when they arrive at junction *A* (Fig. 1) they are made into journeys of four, and thence proceed to the shaft-bottom. The full rope is continued beyond junction *A* into the north-west district, the empty rope being taken through a road or cross-cut, and round a rope-wheel as shown at point *X*, to which is fixed a friction-clutch and a second rope-wheel. The rope so driven draws the coal out of the deep workings.

The north-east district is also worked by the same electric installation, the station being formed over a downthrow fault, 3,750 feet from the pit-bottom. The majority of the coal is delivered to it by a self-acting endless-rope incline. In both instances, tension-pulleys for taking up the slack rope are fixed near to the motor, similar to that shown in Fig. 2 (Plate XXX.); those at the far end station are shown in Fig. 3 (Plate XXX.).

Six Feet Coal-seam (*Fig. 4, Plate XXX.*).—The coals from this seam, which lies 84 feet above the shallow coal-seam, are lowered down a drift by gravitation, a self-acting endless-rope being used, the gradient of which is 10 inches per yard. The coal is drawn at the shallow coal-seam inset. The coals from the south-west districts are brought to the top of this incline by an electric motor working two main-and-tail rope drums. The coal from the north-east districts is drawn by an engine with two cylinders, 8 inches in diameter by 16 inches stroke, geared 4 to 1, but driven by compressed air. These small engines pick up the trains of tubs at various gate-ends, and run with a load of 10 tubs.

This seam has only recently been opened out. An endeavour has been made to reduce horse-work to the lowest possible point by employing these small installations of mechanical haulage, the writer being convinced that a very great saving and economy, in addition to an increased output, can be got by forming roads and concentrating the coals from two or three working-places, and using appliances such as those just described.

Deep Coal-seam (*Fig. 5, Plate XXX.*).—The haulage in the north-east and south-east districts is worked by the main-and-tail rope system; the engines on the surface in both cases have two cylinders, each 14 inches in diameter; they are geared 4 to 1, and fitted with two drums, 4 feet in diameter (Fig. 6, Plate XXX.).

The north-east station is fixed at 5,220 feet from the shaft; the road, after crossing the downthrow fault, is somewhat undulating.

The station of the south-east district is 5,850 feet from the shaft-bottom; for 2,310 feet the road dips, and from this point to the station it rises.

At the present time at the point *A*, Fig. 5, a rock-drift, dipping 7 inches per yard, and intended to recover the coal on the downthrow side of the fault at a depth of 340 feet below the present working-level, is being driven, and advantage is taken to utilize the hauling-rope to bring the loaded tubs of dirt from the back.

A rope is attached to the hind end of the engine-journey and the tubs are drawn out the required distance and then released by a "knock-off" hook (Fig. 7, Plate XXX.); the piece of rope in being drawn in is found useful to steady the empty tubs when going into the back of the head.

The coals are brought from the north districts by endless rope worked by an engine with a single horizontal cylinder, 20 inches in diameter; it is geared 7 to 1, and driven by compressed air. The far station is 6,480 feet from the pit-bottom, and the gradients vary considerably. The tubs are run in sets of four, clipped on at the front and back.

The engine-shed and rock-head districts are now standing, the coals, when working, being brought from them by the main-and-tail rope system, and delivered on to the endless rope at the junction.

Wimblebury Mine.

Top Deep Coal-seam (*Fig. 8, Plate XXX.*).—The coal-seams in this district lie 260 feet above the shaft-bottom level; the system of haulage in use is self-acting endless rope; the gradient varies from 10 to 14 inches per yard; the working load is 15 tons, the load being 50 tubs on each road. Old winding-ropes spliced together are used on this road with most excellent results. Great advantage has been found by increasing the size of the rope; this gives a greater gripping-power for the clips, and putting the tubs in sets of two on at closer intervals has had the effect of reducing the stoppages and mishaps caused by grips slipping, etc.

The surplus power generated by the full tubs going down the incline is used for working the haulage down the side road, at the end of which is fixed the brake-wheel *A*. The wear-and-tear is very little, and with ordinary care 60 to 70 tons per hour can be easily dealt with. The kind of brake-wheel used is shown in Figs. 9 and 10 (Plate XXX.), and for additional security two brake-curbs and straps are provided (Fig. 11, Plate XXX.).

The mines in these working-places lie at angles varying from 10 to 20 inches per yard.

The system of working is longwall, and the working roads are formed 105 feet apart. Cross-roads or gates are frequently formed, the drawing roads being full dip. Brake-chain wheels (Figs. 12 and 13, Plate XXX.) are used for delivering the coals on to the cross-roads from the working-face; they are then taken by horse-power and put on to the next jig-incline, and then lowered on to a lower station and put on to the main hauling-rope and conveyed to the shaft-bottom.

Low Deep, Shallow, and Six Feet Coal-Seams (*Fig. 8, Plate XXX.*).—Owing to a series of large faults, the coals on this side of the pit-bottom are thrown down over 150 feet in various stages.

A considerable output is drawn up this road, which rises 9 inches per yard, and strong haulage-gear is necessary. The power is brought down from the surface by ropes driven by an horizontal engine, with two cylinders, 18 inches in diameter, by 4 feet stroke; it is geared 6 to 1, and the rope-wheel is 6 feet in diameter. In addition to hauling, the engine works a compressor, which generates air for driving an engine fixed in the shallow coal-seam, pumps, etc.

The main haulage-rope goes round the junction *B*. From this point the road rises 6 inches per yard, the coal being lowered on to the main rope at this point by a self-acting incline.

Valley Mine.

Shallow Coal-seam (*Fig. 14, Plate XXX.*).—The hauling on the south-east side is worked by the main-and-tail rope system. The engine, fixed on the surface, has two horizontal cylinders, 14 inches in diameter, and is geared 4 to 1, and has two drums 4 feet in diameter (Fig. 6, Plate XXX.). The ropes are conveyed down the shaft in boxes; this road varies in gradient, and demonstrates how the main-and-tail rope can be utilized to advantage.

From the shaft-bottom to the point *A* the road rises, from *A* to *B* it dips 6 inches per yard, and from *B* to No. 6 station it rises. When starting from the pit-bottom, the main-and-tail ropes are fixed to the journey of tubs twenty-four in number; when it gets to *A*, the tail-rope is knocked off, and owing to the dip of the mine the journey pulls the main rope in with it to *B*. Whilst this is being done, the lengthening rope lying by the side of the road and extending round the return wheel at the far end of No. 6 station is coupled together at *A*, and from *B* the journey of empty tubs and the main rope are drawn to No. 6 station.

In coming out with a full load, both ropes are fixed to the journey, the main rope pulling the full journey and the tail rope out to *B*; at

this point the tail rope is knocked off and the journey proceeds to *A* with the head rope alone. At the point *A*, the tail rope lying round the wheel as left at *A* is attached on and the tubs lowered by it into the shaft-bottom, after being assisted over the summit by the main rope. The advantage of dispensing with the tail rope at the point *B* is that six more loaded tubs can be taken from that point to *A* by not having to pull the weight of the tail rope.

Owing to No. 7 being much lower than No. 6 station, the journey of empty tubs is sufficient to draw the main rope in from *A*, after the tail rope is disconnected.

In this particular road it would have been very costly and troublesome to apply endless rope requiring two lines of rails, owing to the rotten state of the roof and the lifting of the floor.

The south-east shallow coal-seam and ridge deep coal-seam districts are also worked by the main-and-tail rope system, the power being supplied by a horizontal self-contained engine with two cylinders, each 12 inches in diameter.

An endless rope hauls from the north district and also from the deep coal-seam east districts. The far station in the latter district being 4,920 feet from the shaft. From Fig. 14 it will be seen that the tubs are picked up at numerous junctions, and, owing to the various gradients, it is found advantageous to change the clips at the point *K*. The tubs are run in sets of four.

The quantity of coal dealt with by these two roads has exceeded 1,000 tons in eight hours.

The power is derived from an engine with cylinders each 13 inches in diameter (Fig. 15, Plate XXXI.), it is geared down in two steps equal to 16 to 1, and has two rope-wheels and clutch-gear. The engine is fixed in the pit, and is driven by compressed air at a pressure of 60 lbs. per square inch.

Remarks.

Tubs (Figs. 16, 17, and 18, Plate XXXI.).—Wooden tubs are used, the total number employed being about 4,000, all of which are made to a standard size. The framework is of English oak; the sides, ends and bottoms, of larch; strong angle-irons are run inside the tubs, the bodies having a strong hoop round the top. The wheels are of cast steel, 11 inches in diameter, having axles 1¾ inches in diameter. The average weight of coal carried is 12½ cwts., the tare weight of tub is 5 cwts.

Main-and-tail Rope System.—The author will first deal with the main-and-tail rope system. The journeys or setts of tubs vary from

eight on the smaller to forty on the planes worked by the larger engines. To make this system a success, it is very desirable to have straight roads, permanent way well-laid; tubs, couplings, ropes and gearing of all kinds strongly made; and above all good and efficient signals.

The drums on the engines and rope-wheels are all 4 feet in diameter (Figs. 19, 20, and 21, Plate XXXI.).

At the curves, the binding-sheaves are 20 inches in diameter by 8 inches deep (Figs. 22 and 23, Plate XXXI.), placed at equal distances apart from the rail, this arrangement enables each sheave to get an equal bearing. On entering a curve or turn, it is advantageous to make the road slightly curved (Fig. 24, Plate XXXI.); this prevents the rope from rubbing on a large length of rail, and the tubs take the curve better. Check-rails are sometimes used and are placed on the inside of the rails.

The middle-of-the-road rollers are of the same pattern as those used for the endless-rope system (Fig. 25, Plate XXXI.); the cast-iron boxes and bearings work well, keep free from dirt and are easily cleaned; those used for the tail rope are larger in diameter and fixed as required (Figs. 26 and 27, Plate XXXI.).

The upright frames and wheels, reaching from the floor to the roof with the ropes placed through (Figs. 28 and 29, Plate XXXI.), tend to keep the rope in its place on roads having varying gradients. The width of the trod of these pulleys and of the 4 feet wheels is in all cases sufficient to allow the couplings used on the ropes to pass through easily without damage.

It is usual with all setts to have a journey-rider on the train to stop it when required, and, as a warning, a bell and a red light are placed at the leading-end of the train. The average speed run is about 8 miles an hour, the writer being a believer in running big loads at a moderate speed in preference to small loads and quick running.

The size of rope varies from $\frac{3}{8}$ to $\frac{7}{8}$ inch in diameter, a few feet of strong coupling chain with a knock-off hook (Fig. 7, Plate XXX.) being used on both ropes for attaching to the journey. The ropes employed are patent improved steel. On an average they run fifteen months as a head rope and two years as a tail rope.

For detaching at the various points, the rope-coupling (Fig. 30, Plate XXXI.) and the D-link (Figs. 31 and 32, Plate XXXI.) are used. Both are strongly and accurately made from iron of the best quality. The coupling has no rivets. The rope is turned back, the sides pressed to the rope, the ferrule driven up, and the screw-nut keeps it in its place. This arrangement is found to be very convenient, and enables the connexions to be expeditiously made.

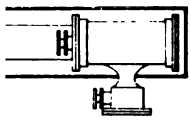
rope-boxes in perfect alignment to prevent unnecessary v them. It is also most essential for the wheels to be sec ample curbing round them, to prevent the rope from either the top or the bottom wheels.

The rims of the wheels are accurately turned, and tı their axles, and the curbing (sometimes of wood or of iro as practicable to the wheel-rims.

Most excellent work and results have been obtained by t rope system of haulage, and for cheapness in first cost, maintenance of road (especially when the roof is bad), of etc., it has many advantages; but, as previously menti tubs, gearing, etc., are well and suitably made, the result as satisfactory as might be desired.

On comparison with the endless rope system, it canno as quantity is concerned, the wear-and-tear being more, tl found this particularly so in the case of the engines, rop etc.

Endless-rope System.—Double roads are used, the tub times singly, and in setts of two, four, and six. The r all cases, under the tub, owing to the coals in many cases feet above the level of the top of the tub. Screw-clips a the coupling-rod being kept long, 3 feet in many cases; be beneficial in going round curves. Screw-clips a gradients varying from 1 to 14 inches per yard, and a damage the rope.

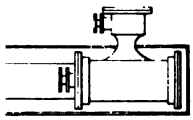


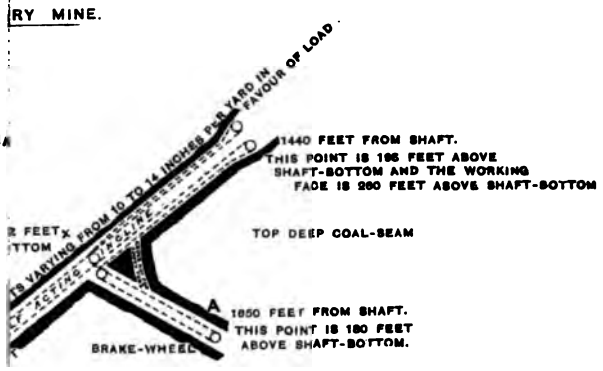
RY MINE.

FIG. 6.

E FOR HEAD-AND-TAIL ROPE HA
MS AND CLUTCH GEARING.

Scale, 8 Feet to 1½ Inches.




IN FAVOUR OF LOAD
1440 FEET FROM SHAFT.
THIS POINT IS 196 FEET ABOVE SHAFT-BOTTOM AND THE WORKING FACE IS 260 FEET ABOVE SHAFT-BOTTOM
TOP DEEP COAL-SEAM
1650 FEET FROM SHAFT.
THIS POINT IS 180 FEET ABOVE SHAFT-BOTTOM.
BRAKE-WHEEL

NORTH EAST DISTRICT

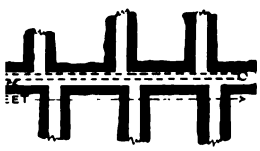


FIG. 12.

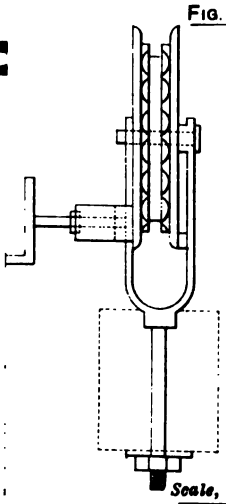
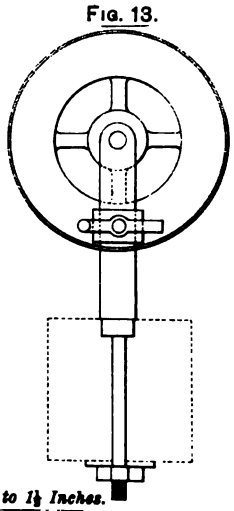


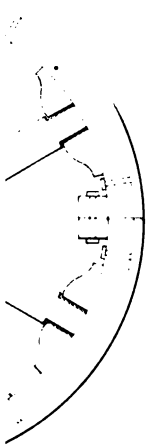
FIG. 13.

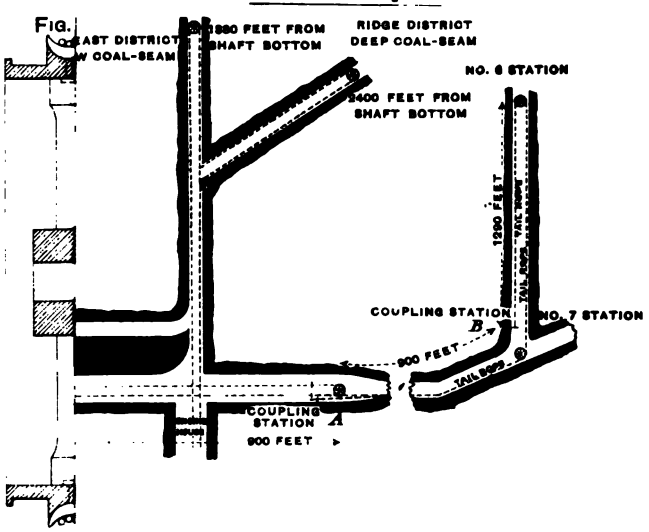


Scale, 2 Feet to 1½ Inches.

CK WOOD MINE.
COAL-SEAM.

FIG.





The boxes for conveying the ropes down the shaft are 4 inches square inside, securely fixed to the shaft sides, and are made of elm or deal, the front planks being so arranged that they can be easily taken off in case anything goes wrong with the rope, etc., in the shaft. Wrought-iron clamps are put on at intervals.

The wheels at the top and bottom of the shaft are arranged as shown in Figs. 33 and 34 (Plate XXXI.). Great care is taken to place the rope-boxes in perfect alignment to prevent unnecessary wear-and-tear on them. It is also most essential for the wheels to be securely fixed, with ample curbing round them, to prevent the rope from getting out at either the top or the bottom wheels.

The rims of the wheels are accurately turned, and truly keyed on to their axles, and the curbing (sometimes of wood or of iron) is set as close as practicable to the wheel-rims.

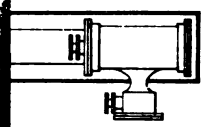
Most excellent work and results have been obtained by the main-and-tail rope system of haulage, and for cheapness in first cost, working, and of maintenance of road (especially when the roof is bad), of rapid extension etc., it has many advantages; but, as previously mentioned, unless the tubs, gearing, etc., are well and suitably made, the results are not always as satisfactory as might be desired.

On comparison with the endless rope system, it cannot compete as far as quantity is concerned, the wear-and-tear being more, the writer having found this particularly so in the case of the engines, ropes, rolling stock, etc.

Endless-rope System.—Double roads are used, the tubs running sometimes singly, and in setts of two, four, and six. The rope is placed, in all cases, under the tub, owing to the coals in many cases being stacked 2 feet above the level of the top of the tub. Screw-clips are entirely used, the coupling-rod being kept long, 3 feet in many cases; this is found to be beneficial in going round curves. Screw-clips are working on gradients varying from 1 to 14 inches per yard, and are not found to damage the rope.

At the various junctions loose points are used as shown in Fig. 35 (Plate XXXI.). Whilst putting on or taking off tubs, the points are put over the rope, grooves being formed in the sleepers, so that the rope can be bound down.

The anchors or binding-sheaves for curves, shown in Figs. 36 and 37 (Plate XXXI.), are securely fastened by four nuts and bolts or coach-screws to timbers running across the road and under the rails. On curves these anchors are placed at equal distances, as shown on the plan (Fig. 38,

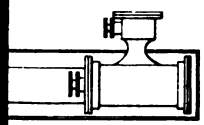


RY MINE.

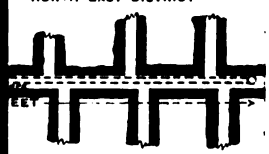
FIG. 6.

NE FOR HEAD-AND-TAIL ROPE HA
UMS AND CLUTCH GEARING.

Scale, 8 Feet to 1½ Inches.



NORTH EAST DISTRICT



CK WOOD MINE.

COAL-SEAM.

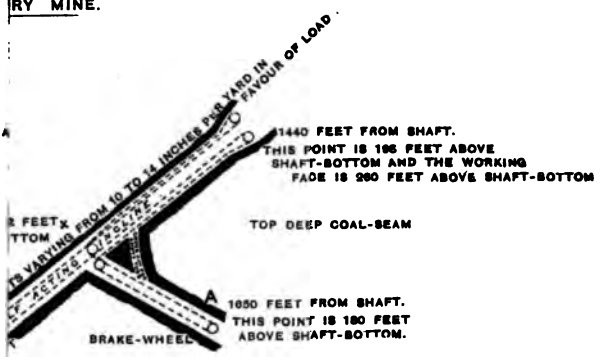

FAVOUR OF LOAD
1440 FEET FROM SHAFT.
THIS POINT IS 196 FEET ABOVE SHAFT-BOTTOM AND THE WORKING FACE IS 290 FEET ABOVE SHAFT-BOTTOM
TOP DEEP COAL-SEAM
1650 FEET FROM SHAFT.
THIS POINT IS 180 FEET ABOVE SHAFT-BOTTOM.
BRAKE-WHEEL

FIG. 12.

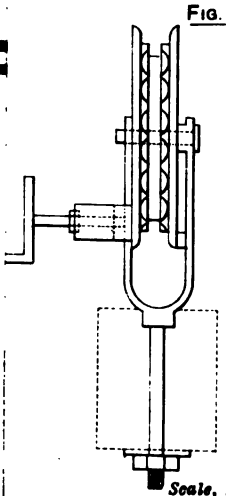
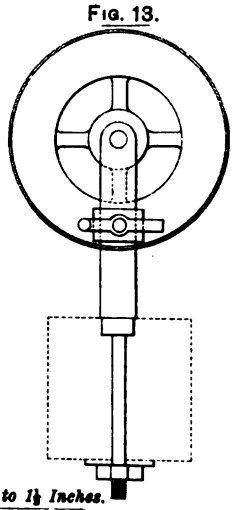
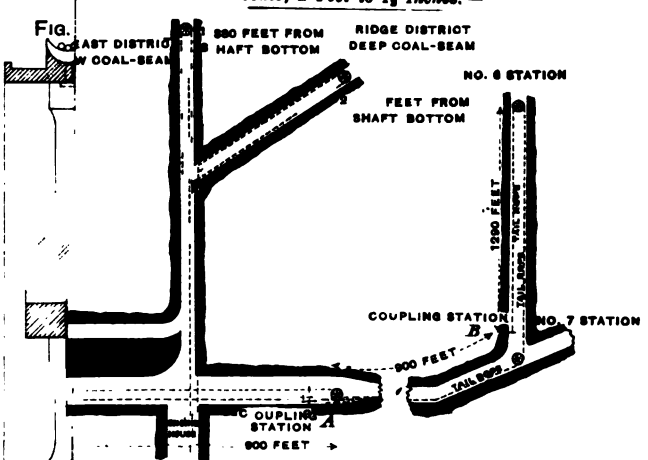


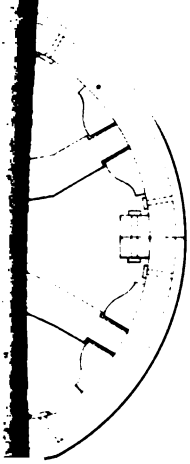
FIG. 13.



Scale, 2 Feet to 1½ Inches.

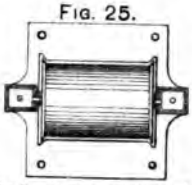
FIG.





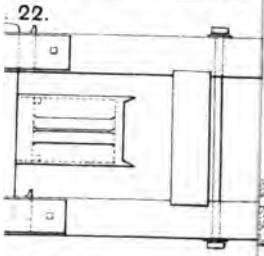
4.

FIG. 25.



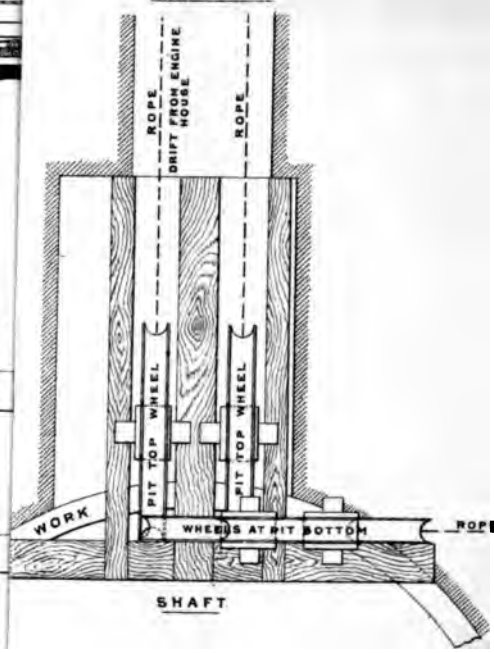
Scale, 2 Feet to 1½ Inches.

22.

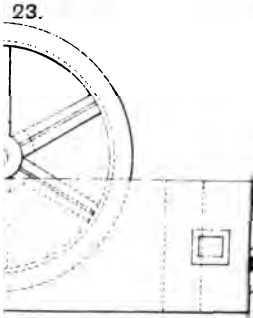


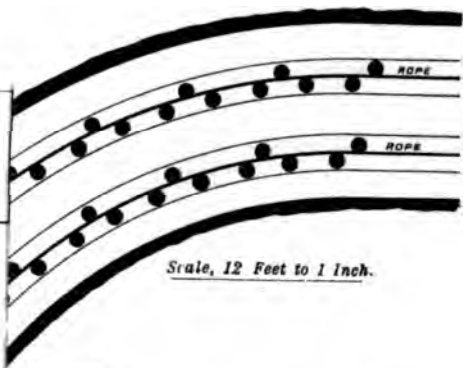
to 1½ Inches.

FIG. 34. PLAN



23.





Scale, 12 Feet to 1 Inch.

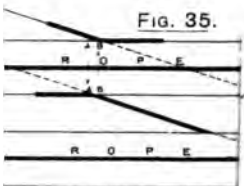
IG. 36

Scale, 2 Feet to 1½ Inche

FIG. 38.

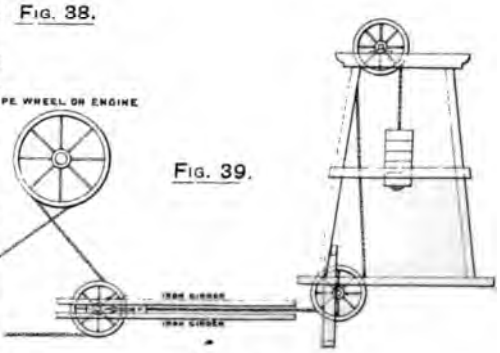
PE WHEEL OR ENGINE

FIG. 35.



Scale, .8 Feet to 1 I

FIG. 39.



Scale, 16 Feet to 1 Inch.

Plate XXXI.), and to prevent the rope from getting off they are sometimes placed alternately on each side of the rope. When so arranged, it is practically impossible for the rope to get off the anchors.

The tension-pulleys are arranged in various ways. Considerable benefit has been found by having one placed as near as convenient to the engine or motor to take up the slack rope as it comes off the rope-wheel. Fig. 2 (Plate XXX.) shows the pattern in underground use near the engine; Fig. 3 (Plate XXX.) is for underground use; and Fig. 39 (Plate XXXI.) is used on the surface.

The tension-pulleys fixed inbye, with balance-wheel fixed and hanging in a staple, have weights varying from 10 to 60 cwts.

The ropes used are from ½ inch to 1½ inches in diameter, and have an average life of 3½ years. The speed varies from 2 to 3 miles per hour.

The tubs are clipped and unclipped whilst the rope is running, on the rope driven by power. The tubs on roads working by gravitation or steep gradients are clipped on and off whilst standing; this enables them to be more securely gripped and put on the rope at proper intervals.

Road.—The gauge of the road at the Cannock Wood mine is 19 inches, and at the Valley and Wimblebury mines, 26 inches. The engine-roads are all laid with steel rails weighing 18 lbs. per yard, fished and chaired (the chairs being made from wrought iron). Wooden sleepers are placed every 3 feet, and nearer where necessary.

Signals.—Electric signals are used throughout the various seams, two wires being run along the road with batteries of Leclanché cells fixed at each end.

Cost.—In dealing with the working cost of each system, the writer has taken the cost of labour only into consideration, as the first cost of erecting plant, maintenance, etc., depends upon the particular circumstances connected with each case.

The average cost for labour on the main-and-tail rope system is 0·60d. per ton, and in some instances it is as low as 0·45d. per ton. The endless rope costs 0·66d. per ton on the quantity at present dealt with. It is, however, only fair to say that the quantity could be considerably increased without any additional cost in labour.

The PRESIDENT moved that a vote of thanks be accorded to Mr. Williamson for his paper.

The motion was approved.

The meeting then closed.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE MASON COLLEGE, BIRMINGHAM, JUNE 18TH, 1896.

MR. J. H. COOKSEY IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. R. E. BERINGER, Mining Engineer, Durango, Mexico.
Mr. JAMES BLANE, Mining Engineer, Johannesburg, S.A.R.
Mr. E. COWELL, Electrical Engineer, Johannesburg, S.A.R.

STUDENTS—

Mr. G. W. JOHNSON, Mining Student, Camborne.
Mr. A. S. WHELER, Mining Student, Camborne.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

MR. W. F. CLARK, MR. W. J. HAYWARD, and MR. H. C. PEAKE.

TECHNICAL EDUCATION.

The County Council have been advised by your Committee to hold a Scholarship Examination for North and South Staffordshire at Stafford, Messrs. W. Beattie Scott and W. N. Atkinson, H.M. Inspectors of Mines, being Examiners.

The discussion of several papers was adjourned.

The meeting was then closed.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

ACETYLENE LAMP.

Lampe à l'Acétylène. ANON. *Journal Mensuel de l'Académie Nationale, Agricole, Manufacturière et Commerciale, December*, 1895, *with three illustrations.*

The Trouvé portable acetylene gas-lamp resembles an ordinary oil-lamp in its outward appearance. The body of the lamp, holding water, contains a closed vessel pierced with a hole at its bottom, in which a metallic wire-cage is suspended, filled with pieces of carbide of calcium. The theoretical working of this lamp is similar to that of the ordinary sulphuretted-hydrogen apparatus of the laboratory. The water in the reservoir of the lamp enters into the closed vessel from below, upwards through the hole pierced at its bottom. As soon as the water in the closed vessel reaches the pieces of carbide of calcium placed in the wire-cage, there is an abundant evolution of acetylene gas, which flows into the upper part of the closed vessel, drives the water downward, and breaks the contact between the water and the carbide of calcium. The production of gas is, consequently, stopped as soon as the gas produced ceases to be burnt in the upper part of the lamp, in the ordinary manner with a small burner.

Mr. Trouvé is also the inventor of a similar arrangement by means of which acetylene gas may be stored in an ordinary gasometer.

Great care is required in the preparation of acetylene gas from carbide of calcium in contact with water, as pressures exceeding 200 lbs. per square inch may be easily produced, resulting in the entire destruction of the apparatus.

M. W. B.

THE CRÉDO DEPOSIT OF ASPHALT AND PETROLEUM, FRANCE.

Note sur le Gisement de Pétrole et d'Asphalte du Crédo. By — BOULANGIER. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, *page* 14.

The recently discovered deposit at the Crédo, on French territory near the Swiss frontier, contains beds of sand impregnated with a viscous petroleum rich in paraffin, running from the sand as soon as the beds are cut, and, strangely enough, flowing at and from the altitude of 2,952 feet (900 metres). A second substance of the hydrocarbon family, asphalt, has also just been discovered.

Crédo lies midway between the two most important asphalt mines, that of Seyssel in France, and that of Val-de-Travers in Switzerland. J. W. P.

DUST-FIRING IN BROWN-COAL BRIQUETTE WORKS.

Ueber Stauberzeugung und Kesselfeuerung in der Braunkohlen-Brikettfabrikation. DR. KOSSMANN. *Berg- und Huettenmœnnische Zeitung*, 1896, *vol. lv., pages* 45 *and* 61.

More coal-dust is produced in the operation of making brown-coal briquettes than in any other branch of mining industry except the dry sifting of small coals. The utilization of this dust for firing the boilers, etc., is however, neglected on the score that there is not enough produced to afford a constant supply, and that it would not be worth while to fit merely a few of the furnaces with the requisite appliances. At present, the method of firing adopted is wasteful, the thick layer of coal on the sloping furnace-bed needing a greater draught than is absolutely requisite for combustion, so that the gases pass away into the chimney before they have yielded up their heat, about 34·6 per cent. whereof is thus wasted. An additional waste of heat is caused by the presence of a high percentage (45 to 55) of water in the coal, nearly one-half being in a state of chemical combination. The gain from coal containing 13 per cent. of moisture, as compared with the same coal with 18 per cent. of moisture, supposing 28 tons to be consumed per diem shows a monetary saving for 10 boilers per annum (300 days) of nearly £640.

In making brown-coal briquettes, the dust is chiefly produced in the drying-ovens, and the elevators conveying the dried coal to the presses. In the former case, the dust is partly carried away by the water vapour evolved from the coal, the remainder being deposited in the ovens or the collecting box for the dry coal. In the other instance, most of the dust is drawn into chimneys by an exhaust fan, a portion, however, settling on the presses and constituting the driest grade. Some 40 cwts. of dust have been collected in a day of 24 hours at a works employing four presses. In consequence of the danger of explosion, it has been found advisable to exhaust the whole of the dust by a system of exhaust fans wherein it is met by jets of water and collected in a tank, partially dried, and thrown away.

C. S.

PROPFE MILL FOR COAL-DUST FUEL.

Ueber Kohlenstaub-Müllerei mittelst Propfe-Mühlen. By S. E. *Oesterreichische Wollen und Leinen Industrie*, 1896, *vol. xvi., page* 174.

In ordinary disintegrators, the speed is of necessity so high, in order to produce an impact of the coal against the bars sufficient to break the former down, that the apparatus is constantly endangered by the risk of foreign bodies (metal, etc.) getting into and breaking it. On the other hand, mills, in which the crushing power is exerted by spherical rollers, have only a comparatively small working-face, and lose much power in friction.

In the Propfe mill, both the centrifugal and spherical-roller principles are combined, the grinding-chamber containing two sets of rollers set loosely between horizontal guides attached to an upright shaft, and working against a heavy ring of iron. This arrangement allows lumps of unequal size to pass into the mill, and as the coal is crushed between two masses of metal, the pressure of which can be varied by altering the speed, the rate of rotation can be sensibly reduced, the speed actually required being between one-seventh and one-twelfth that of the disintegrating mills.

One set of rollers is situated in the upper part of the grinding-chamber, and the other at the bottom. The intermediate space is occupied by a number of fan-blades mounted on the main axle, which blow out the coal-dust through the per-

forated sides of the chamber into an outer case. The portions of coal insufficiently ground by the upper rollers fall, and are finished by the lower set.

This mill is said to be capable of grinding (working with 12 to 18 horse-power at 200 revolutions a minute) 20 to 50 cwts. of hard coal, or 16 to 45 cwts. of brown coal, per hour, at a cost of 1s. 3d. to 1s 6d. per ton for dust fine enough to pass through a mesh 0·012 inch in diameter. At the Anhalt colliery (Frose), between 30 and 31 cwts. of dust were recently ground per hour, with an expenditure of 17·1 horse-power. As about one-fourth of the power was employed in driving the elevator, intermediate gearing, and other auxiliary machinery, it may be reckoned that the actual capacity of the mill was 2½ cwts. of dust per hour for each horse-power employed. C. S.

COAL-DUST FURNACES.

Ueber Kohlenstaubfeuerungen. By F. BLEICHSTEINER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv.*, *pages* 237-240.

Notwithstanding that for some kinds of furnaces coal-dust firing is less easy to regulate than gas, it will be found preferable to the latter in other cases, such as those where a constant high temperature without oxidizing flame is required—long furnaces for ingots, for example, the coal burning without excess of air. Again, in the several stages of working puddling gas-furnaces, where not only are variations of temperature required, but also facilities for producing at will a reducing or oxidizing flame, it is found that for coal-dust a compressed-air draught is useful in order to render the rate of combustion independent of the natural draught of the chimney stack, which latter varies continually in accordance with the prevailing atmospheric conditions. This is of importance when a hot-air blast is used, the temperature in that case rising rapidly and increasing the consumption of coal, which is necessary in large furnaces, and cannot be so well effected by using larger spraying-nozzles, or increasing their number.

Although there is a general consensus of opinion in favour of dust-fuel, doubts are expressed whether the cost of grinding, etc., will not swallow up the advantages derived in other ways. There is also the question of sacks; but these will not increase the cost by more than 1d. per ton, including repairs, 1 cwt. sacks, that may be filled a hundred times, being purchasable in Vienna at rather less than 3d. apiece.

Wet coal, *i.e.*, coal that has been washed, or contains more than the ordinary percentage of moisture usually found therein when it leaves the pit, is unsuitable for grinding, as it clogs up the disintegrator, and necessitates an increase of driving power to about two and a half times the normal amount. Even in ball-mills, though to a less extent, damp coal does not grind satisfactorily. Where, however, the coal has only the natural quantity of moisture, it pulverizes easily, and the choice of mills is simplified into a consideration of the relative cost of initial outlay and maintenance. The following figures show the cost of grinding:—

A disintegrator capable of grinding 8 to 8½ tons of coal-dust per 12 hours, fine enough to pass through a sieve of 0·012 inch mesh, will cost about £125, and require a 10 horse-power engine. The cost of working will be:—

	s.	d.
Power, per 12 hours	4	9
Attendance	2	3
Wear of plant	1	0
Redemption of capital, 25 per cent.	1	6
Total	9	6

per diem for 8½ tons, or less than 1s 3d. per ton.

A ball-mill will cost £200, and require a 12 horse-power engine to produce 9 to 10 tons per diem, the expenses of grinding being about 1s. per ton, including repairs and wear of plant at £10 15s. per annum, and writing off 10 per cent. of the cost. Vertical ball-mills will be more expensive to work, the wear and tear being greater. If water-power be available, the cost of grinding would fall to about one-half the above-named estimated cost.

A caution may be addressed to those who think that their difficulties are at an end so soon as they have purchased a coal-firing apparatus; they will speedily find that the process requires to be worked with care and intelligence, if good results are to be obtained. C. S.

POWDERED COAL-FIRING.

Ueber die Fortschritte in der Kohlenstaubfeuerung und die Anwendung derselben im Hüttenwesen. By VICTOR V. NEUMANN. *Zeitschrift des Oesterreichischen Ingénieur-und Architekten Verein, June 5th,* 1896, *and drawings.*

The different systems of powdered coal-firing have been already described in a paper read before The Federated Institution of Mining Engineers by Mr. Bryan Donkin.* There are five methods now before the public, the Wegener, Schwartzkopff, Friedeberg, De Camp, and Ruhl. The principles governing the combustion of powdered coal are so different from those hitherto usual, that they naturally make their way slowly. In ordinary firing, a thick layer of coal is spread over the grate. Combustion takes place only on the surface, and can never be uniform, because it is impossible to regulate the quantity of air in proportion to the coal burnt. In powdered coal-firing only as much combustible is admitted at a time as will burn, with a corresponding quantity of air fed in by the chimney-draught or forced blast, and the supply of both is continuous. The powdered coal surrounded by the oxygen of the air burns away at once without any reserve of glowing fuel in the furnace. The economy and relatively perfect combustion depend upon the proportional quantities of coal and air, and the latter may be reduced to the theoretical amount required for complete combustion. This is the chief advantage of powdered coal-firing. To ensure it the following conditions are requisite:—

1. The coal must be finely and uniformly ground.

2. An apparatus, more or less complicated, usually driven mechanically, is necessary to introduce it into the furnace.

3. A combustion-chamber, lined with fire-brick and maintained at a high temperature, is essential, because there is no grate, and no mass of burning fuel to ignite the powdered coal as it enters.

4. The volatile ash formed by the incombustible residuum must be removed easily and quickly.

The advantages of powdered coal-firing are:—Economy of combustible and utilization of the poorer kinds of coal; less attendance required; no smoke.

The main difficulty is to grind the coal. The production of a good coal-grinding mill is of such importance that the general adoption of powdered coal-firing seems to depend chiefly on it, and the subject is now occupying the attention of many engineers. The coal must be reduced to a powder as fine as cement, crushed to an uniform size, and passed through a fine sieve: it must therefore be both ground and sifted. Any kind of small coal may be used, except lignite, but it must be dry, and should be kept under cover until wanted. In many cases the cost of grinding is covered by the difference in original price between the poor coal and dust utilized, and the large coal generally required.

* *Trans.*, vol. xi., page 321.

There are three kinds of coal grinding-mills: disintegrators, ball crushing-mills, and centrifugal rolling-mills. The first are suited for grinding hard coal, but only if perfectly dry, and a separate sieve is necessary. The ball crushing-mills also require a sieve and much power to drive them, will only grind dry coal, and are rather dear. The disintegrators deliver per hour from 110 lbs. to 2,200 lbs., and require from 1 to 8 horse-power to drive them. The ball crushing-mills deliver from 110 lbs. to 1,100 lbs. per hour, and require from 1½ to 11 horse-power. The newest and best are the centrifugal rolling-mills. They are efficient, not susceptible to moisture in the coal, and clean—all the machinery being enclosed. They will deliver 220 lbs. per horse-power per hour, and grind lignite containing 20 per cent. of moisture. All that is required with these mills is to feed in the coal at the top, and withdraw the automatically filled sacks at the bottom. A small disintegrating mill has been working in an Austrian foundry for a year. It delivers 440 to 550 lbs. of coal per hour, and requires 2 to 3 horse-power to drive it. It is the only continuous coal grinding-mill in Austria, and has supplied powdered coal for all the experiments. The coal costs about 2s. 1d. per ton to grind, but this price will probably be reduced before long, and it is already covered by the poorer coal used. The grit and dross now employed to fire a welding-furnace were formerly thrown away. There is still, however, much prejudice against powdered coal, and it will not be generally adopted until it can be bought ready for use, like other kinds of combustible. At many mines, large quantities of coal-dust, at present of small marketable value, might be cheaply ground on the spot, and turned into good serviceable fuel. It is in the interest of mine-owners to grind their coal, and thus supply a want which has hitherto been the chief hindrance to the spread of powdered coal-firing.

The second requisite in all powdered coal combustion, except the Wegener furnace, is motive power to introduce the coal, either by means of compressed air or a rotating apparatus. If Mr. Wegener succeeds in utilizing the chimney-draught, he will have made an important step in advance. In the other four types motive power is required.

The Schwartzkopff apparatus is the only one hitherto used in Austria. It consists of a rapidly rotating steel-wire brush, which sweeps the powdered coal into the combustion-chamber. The coal is conveyed to the brush through a shaker, and is introduced into the furnace mechanically and separately, instead of being carried along, as in all other systems, with the air for combustion. The latter enters independently, and its admission is carefully regulated. As with this apparatus the air may be highly heated, the surplus heat from the furnace can be utilized for the purpose, and this is of great importance in metallurgical work. The Schwartzkopff brush makes 900 revolutions per minute, and requires about 0·10 horse-power to drive it. A welding-furnace has been working successfully, and without intermission, since May, 1895, at Marktl, in Austria.

The third requisite is a highly heated combustion-chamber, lined with fire-brick, to ignite the coal; the higher the temperature the better the combustion. The chamber is easily arranged in Lancashire boilers, by dividing them in two with a small fire bridge, which converts one end into a combustion-chamber. Part of the boiler heating-surface is thus lost, but more complete combustion is obtained, and a high initial temperature of the gases. With water-tube boilers, furnaces with arches and a series of holes give the best combustion. In metallurgical furnaces, which are throughout at the same high temperature, no difficulty is experienced, and the combustion-chamber can be made much smaller. The necessity for it is not a drawback, but an advantage, because almost perfect com-

bustion can be ensured. With a high furnace temperature, water and carbonic acid gas are formed, with poor combustion, soot, smoke, and much carburetted hydrogen. These chambers also retain the heat when the boiler or furnace is not in use.

The fourth difficulty with powdered coal fuel is the incombustible residuum, which cannot of course be burnt, but forms a light and easily removable clinker. By properly directing the air-current the solid particles carried off with the flue gases can be deposited in a given place. With pure coal containing little ash, the structure of the boiler need not be altered, but where there is much clinker and ash care must be taken to facilitate their removal. It is sometimes necessary to have two ash-boxes, one in front and one behind the boiler. In a cement-factory, near Saarbrücken, 4 sets of Schwartzkopff apparatus have been working for months with coal containing 44 per cent. of ash and non-combustible substance, and no difficulty has been experienced.

Up to the present date (1896), 5 boilers in Austria have been fitted with the Schwartzkopff firing. The coal used is Ostrauer small, containing about 17·8 per cent. of ash. The first boiler was in Vienna, and had *bouilleurs* above and one large tube below. Fired in the ordinary way with good Silesian coal, it evaporated 5 lbs. of water per hour per square foot of heating suface. With the Schwartzkopff apparatus and greatly forced, the boiler evaporated 7 lbs. of water per hour per square foot of heating surface, or an economy of 29 per cent. over ordinary firing, apart from the difference in quality of the coal. The temperature of the flue-gases was 450 degs. Cent. A water-tube boiler with Schwartzkopff firing was much forced for months. No experiments could be made, but the large quantity of water evaporated showed that the apparatus worked well, even when the brick combustion-chamber was red hot. Two other small boilers have been fitted with Schwartzkopff firing, but no regular experiments have been made with them. A Dupuis boiler gave, during a preliminary trial, an economy of 15 per cent. of coal.

In foundries, excellent results have been obtained, and it may be said that for this class of work powdered coal firing is likely to be even more extensively used than for boilers. The first smelting-furnace with Schwartzkopff firing was set up at Messrs. Neumann's works at Marktl, and has been working continuously since July, 1895. A puddling-furnace was next added, and now all the furnaces in this foundry have been similarly re-modelled. In three other places, a coal grinding-mill and smelting-furnace have lately been put up. The chief advantage of the Schwartzkopff apparatus for foundry work is that the surplus heat of the powdered coal firing is utilized to heat the air for combustion. In metallurgical furnaces all the operations are carried out between narrow working limits, and at very high temperatures, and even the most perfect combustion can only be economical if the surplus heat is utilized. Hence the Schwartzkopff system is especially suitable, because in it the air for combustion is introduced separately and can be previously heated. If the air has to carry the powdered coal along with it, and to pass through all the mechanism for sifting and admitting the fuel, it must part with most of its heat before it enters the furnace. At Marktl, two of the furnaces have recuperators. On leaving the furnace, the flames or hot gases pass between these pipes on their way to the chimney; the air circulates through them in the reverse direction before entering the furnace. The third furnace has a dust-absorbing chamber but no recuperator, showing that even with cold air a proper welding heat may be attained; in such a case the excess of heat in the furnace may be utilized to generate steam.

The results obtained with powdered coal as compared with the Boetius gas-furnaces formerly used are very favourable, showing in some cases an economy of

coal of 40 per cent. and an increased production of 25 per cent. Formerly in welding-furnaces there were from four to six furnace-charges per shift, now there are from five to eight. The consumption of coal is diminished one-third, and 100 lbs. of pure iron are produced from 120 instead of 128 lbs. as formerly. The waste is also less. This foundry is on a small scale, and the rollers work slowly. From 110 to 154 lbs. of raw and scrap iron are rolled out into thin plates in 20 to 25 minutes, and this affects unfavourably the efficiency of the furnace. With the Schwartzkopff firing in a twelve hours' shift, and eight single charges, 6 tons of pure puddling bars were obtained from 6·4 tons of iron. The consumption of coal was 18·7 lbs. per 100 lbs. of bars, a result which has seldom been exceeded even in large regenerative gas-furnaces. In quick puddle-firing, there were formerly fifteen to seventeen furnace-charges per shift, with a coal consumption of 1·6 tons to 1·7 tons; with powdered coal-firing, there are twenty-two to twenty-four charges, and the consumption of coal is 1·1 to 1·2 tons, or 50 per cent. economy. Feeding the furnaces is a safe and simple operation, requiring little stoking and few men. Heating up by means of a small auxiliary grate is effected more rapidly than in grate furnaces. A wood or coal fire is kept up for an hour till the combustion-chamber is hot enough to ignite the powdered coal which is then introduced, and in three hours the whole furnace is at a white heat. The same method is adopted in boilers. The time occupied depends on the temperature of ignition of the coal; lignite catches easily, coke and anthracite take longer to burn, and if they are used it is better to begin with a sack of lignite. No explosions of powdered coal have occurred, and they are only possible with very unskilful stoking, if the flues are allowed to get choked with unburnt powdered coal. This fuel is safer than gas for firing. The coal is introduced through an adjustable screw, air through the dampers, and the admission of both is regulated easily. Even with very damp coal the apparatus will work.

Analyses of the gases of combustion give from 15 to 17 per cent. of carbonic acid, 1·3 per cent. of carbon monoxide, and 0·6 per cent. of oxygen. It is not necessary to open the fire-doors or clear the grate, but the ash must be occasionally removed and the recuperator cleaned. The sulphur in the coal burns as easily as on a grate. The character of the incombustible residuum can be determined from the analysis of the coal. The quantity of volatile ash deposited in the furnace depends on the draught, regulated by the dampers.

Powdered coal-firing has in nine months yielded results so excellent that they outweigh the disadvantages of grinding the coal, transmitting the power, and removing the ash. If in small ironworks with three furnaces and a yearly coal consumption of 275 to 285 truck-loads, from 90 to 150 truck-loads can be saved, the production of iron increased, and cost of labour diminished, it may safely be asserted that powdered coal-firing forms an almost ideal combustion for nearly all kinds of metallurgical work, and is far preferable to gas-fired furnaces. The economy obtained is 20 to 30 per cent. in boilers, and 30 to 40 per cent. in smelting-furnaces. As the apparatus does not produce any smoke there is none for it to consume. If this good result can be permanently maintained, powdered coal-firing will greatly contribute to the solution of the smoke-abatement question.

B. D

THE COMBUSTION OF COAL IN AIR.

Zur Verbrennung von Kohle in Luft. *By* ALEX. NAUMANN. *Zeitschrift für angewandte Chemie*, 1896, *page* 200.

The results of experiments performed in the author's laboratory lead to the conclusion that the formation of carbon dioxide begins at about 400 degs Cent. and increases rapidly up to between 500 and 700 degs. Cent. when the maximum (20 per cent. of the evolved gas) is obtained, with complete consumption of the oxygen provided the air-current be not too rapid. At the above temperatures, a little carbon monoxide is formed, both when the draught is slow and the layer of coal long, but at about 900 degs. Cent. its formation increases, and at 1,000 degs. Cent. and above, no carbon dioxide is produced, all the carbon burning into monoxide with complete consumption of the oxygen.

The formation of carbon monoxide direct and by reduction of the dioxide was proved by direct experiments, it being found impossible to completely reduce the dioxide by means of coal at 1,000 to 1,100 degs. Cent., thus proving that the dioxide is not produced at these temperatures, otherwise a certain proportion would be found unreduced amongst the products of combustion.

The subjoined table shows the percentage composition of the flue-gases at different temperatures of combustion:—

Temperature. Degs. Cent.	Percentages by Volume. Carbon Dioxide.	Carbon Monoxide.	Oxygen.
375	0·5	0·0	20·0
401	6·2	0·8	12·3
495	19·0	1·6	0
675	19·8	1·1	0
700	18·0	2·5	0
800	17·9	5·9	0
900	10·1	15·8	0
950	0·6	31·5	0
995	0·0	34·4	0
1,000	0·0	34·2	0
1,075	0·0	34·6	0
1,092	0·0	34·4	0

Theoretically, the percentage of carbon monoxide resulting from the complete conversion of the carbon into monoxide, would be 34·3, and that of nitrogen 65·7.

C. S.

THE SMOKE QUESTION.

Neue Beiträge zur Rauchfrage. *By* MESSRS. VON SCHRÖDER *and* W. SCHMITZ-DUMONT. *Dingler's Polytechnisches Journal*, 1896, *vol.* 300, *pages* 65, 111, *and* 136.

The authors subjected a number of young pines, firs, maples, and lindens to the action of dilute sulphurous acid gas ($\frac{1}{10000}$ to $\frac{1}{100000}$) daily for some weeks, in order to ascertain the minimum limit of the dilution capable of injuriously affecting vegetation. It was, however, found that in all the experiments the trees sickened, although in some cases the sulphurous acid was no longer perceptible to the senses, the effects produced being practically the same whether with short

periods of exposure to more concentrated gas or with longer exposures to the gas in a state of greater dilution. The leaves or needles, particularly those on the new shoots, turned grey, then reddish brown, and finally dropped off. The percentage of sulphur in the leaves was much higher, being in some instances twice or thrice the amount originally present, from which circumstance, coupled with the fact that where the plants were merely watered round the roots with dilute solutions of sulphurous acid no unfavourable action followed (although the quantity of sulphuric acid absorbed therefrom by the leaves was larger than that resulting from the direct absorption of the gas), it is concluded that the damage is caused by the contact and absorption of the acid gas into the substance of the plant through the leaves alone. It is also believed that this is true in the case of other acid gases, and especially of hydrochloric acid.

Further experiments were carried out to determine whether rain has, as is sometimes asserted, the power to wash out some of the sulphurous acid absorbed by leaves exposed to smoke. The results of these investigations go to show that, in the case of such plants as potatoes, the absorbed acid gas may be fully extracted from the dead leaves by the action of rain but not from those still in a condition of vitality. On the other hand, in the case of resinous or waxy leaves, water is incapable of washing out the acid, even in dead leaves, unless under abnormally favourable conditions, such as are little likely to occur in nature. In fact the authors' conclusions, derived from their work, are to the effect that it is practically impossible for the damage occasioned by smoke to trees, particularly those whose leaves contain wax or resin, to be remedied by the re-extractive action of rain, more especially since any small amount of acid so washed out would be, in districts where smoke constantly prevails, immediately replaced by the absorption of a further quantity. C. S.

EXPANSION-DAMPERS FOR THE FURNACES OF BOILERS WITH SMALL WATER-TUBES.

Les Trappes d'expansion de Vapeur des Fourneaux de Chaudières. By C. WALCKENAER, *Secretary of the French Commission Centrale des Machines à Vapeur. Annales des Mines*, 1896, *vol. ix., page* 521.

In a communication to the *Annales des Mines** as to measures for increasing the degree of safety in steam-boilers with small water-tubes, the principle was indicated for ensuring an easy and harmless issue to the steam in the event of a water-tube bursting. Since that time, two arrangements, fitted in Paris, with this object, have been practically tested by the bursting of tubes, and appear to have acted satisfactorily. Both the arrangements were applied to Belleville boilers at central electric stations, one having been designed by Mr. Delaunay, and the other by the Edison Continental Company.

Choice between the two systems must depend on local conditions, especially on the ventilation of the stokehole and the arrangement of the smoke-flues, while the design must vary with the form of the boilers. For instance, the Babcock & Wilcox Company, as the result of a recent study of this question, has decided in future to place expansion-dampers to the right and left of the steam-collecting tubes of its boilers, in that part of the side-walls where formerly there were only simple working-holes for sweeping the flues; but, as the expansion-damper rests upon an inclined frame, special precautions must be taken to prevent its fall into the stokehole.

* Vol. vi., 1894, page 534.

These arrangements, however, constitute only half the programme of safety measures, the other half consisting of strongly barricading the fronts of the boilers, while it is also important that there be no parts, such as bricks, that might be blown into the stokehole. As regards the doors of the tube-boxes, one of the best precautions appears to consist in ensuring their closing by the addition of a horizontal bar, firmly fixed right and left to the metal framing. In the case of ordinary grate-furnaces, the autoclave arrangement of doors opening inwards is to be recommended. A further improvement, according to Mr. Bochet, consists in arranging the doors so that if, when they are opened, a pressure should be set up inside the furnace, they would always be free to close automatically, having indeed a tendency to do so; and this might perhaps afford protection in cases when, owing to a tube bursting while the furnace is being fired, the stoker is exposed to the greatest danger, as proved by a fatal accident from this cause which occurred at Paris in January last.

As regards the ash-pits, the best plan would evidently be to leave no permanent opening into the stokehole; but makers hope to obtain the necessary safety in this respect by providing them with swing doors, or special dampers working on a horizontal axis, so as to close under the slightest current of gas in the direction contrary to the normal air-current. J. W. P.

THE DUBIAU WATER-CIRCULATING APPARATUS.

Der Apparat von Dubiau. ANON. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv., pages* 134 *and* 135.

The Dubiau apparatus is used for promoting the circulation of water in boilers, thereby raising steam more quickly and preventing incrustation. It is claimed that with this apparatus, the water circulates 60 to 100 times each hour, and that the quantity of steam raised per lb. of coal burnt is increased.

Taking for example a Cornish boiler. Two thin metal plates, slightly curved, are placed one on each side of the furnace-tube for the whole length of the boiler, a flat metal sheet is riveted to the top ends of these curved plates through which small tubes are inserted, cut obliquely at the lower end. The tops of these tubes reach into the steam space above water-level. Along the top of the boiler a thin impinging plate is bolted.

The cooled water falling to the bottom of the boiler passes between these curved plates and the furnace tube, part of the water here being converted into steam, and steam and water pass through the tubes on the top plate into the steam space above. A. N.

RAKY SYSTEM OF BORING.

Das Rakysche Tiefbohr-Verfahren. ANON. *Glückauf*, 1896, *vol. xxxii., pages* 225-232, *and five figures.*

The Raky is an improvement on the Fauvelle system of hollow rods, armed with a cutting chisel, and chiefly relates to the method of imparting motion to these rods. They are suspended in the usual way to one end of a lever, which is pivoted on an axle carried on springs, so as to diminish the violence of the shock and prevent breakages. The weight of the rods can be counterpoised if desired. The other end of the lever is connected by a connecting-rod to a crank on the face of a pulley, which is driven by a slack belt, the necessary friction being produced by a tightening pulley applied to the following side of the belt. This tightening

pulley is so pivoted that when the rods are about to fall the tightener is drawn back from the belt, and the rods can fall freely at a speed higher than corresponds to the motion of the crank at the bottom of its stroke. By this means, too, the machine can work as fast as 80 strokes per minute, and a speed of 130 to 190 feet of boring has been accomplished in twenty-four hours. In the past year, a bore-hole was put down successfully by this method for petroleum at Gunstell, in Alsace. The erection of the boring-plant took 26 working days, and, boring to a depth of 1,304 feet 6 inches, took 332 hours actual boring, 91 hours more being taken up with tubing the borehole. The speed of boring was therefore nearly 4 feet per hour's work. Two eleven-hour shifts were worked, there being in each one foreman and five labourers. The cost was as follows:—

	£	s.
Wages	127	12
Repairs	16	19
Oil and lubricants	3	1
Coals	30	0
Material	6	13
General expenses	23	12
Transport	12	13
Total	£220	10

Which, on the above total of 1,304 feet 6 inches, amounts to about 3s. 4d. per foot.

H. L.

DETERMINING THE CALORIFIC VALUE OF FUEL.

Détermination du Pouvoir calorifique des Combustibles. *By* E. GOUTAL. *Revue de Chimie Industrielle*, 1896, *vol. vii.*, *pages* 65-67.

Up to the present time, chemists have not been successful in establishing any satisfactory method of determinating the calorific value of fuel, the estimates given by different analysts on the same material frequently varying by as much as 10, or even 15, per cent.

Prof. Berthier in 1834, proposed to estimate calorific value by the reducing effect of the fuel on litharge; but this was found unreliable, since the amounts of carbon and hydrogen able to reduce a given weight of lead have a calorific ratio of 34·5 to 24·42, and therefore in fuels containing a relatively high proportion of hydrogen to carbon the results would be below the truth, and *vice versa*.

Prof. Dulong's formula, and that enunciated by Prof. Mahler, give results which agree pretty closely with those obtained with the Mahler bomb, but the formulæ proposed by Messrs. Scheurer-Kestner and Meunier, Cornu, and Ser exceed actual measurements by percentages ranging from 3 upwards. In any case, seeing the discrepancies in the results furnished by different analysts, it is better to leave formulæ based on ultimate analysis out of the question.

Dr. Gmelin's formula, in which cognizance is taken of the amount of moisture in air-dry material, and the percentage of ash, cannot be considered reliable, these two factors being comparatively insignificant.

The most suitable basis for a formula is, in the author's opinion, the fixed carbon, which has a definite calorific value, and the volatile matter, the amount of heat evolved by the latter during combustion being fairly regular for the same variety of coal. He therefore proposes to take:—

$$Q = 8{,}150\ C + A \text{ (volatile matter)},$$

wherein A is a quantity equivalent to 13,000, when the proportion of volatile matters is between 2 and 15 per cent.; 10,000 when between 15 and 30 per cent.; 9,500 for 30 to 35 per cent. and 9,000 for from 35 to 40 per cent. The results calculated in this manner approximate closely to those of direct determinations by the Mahler bomb, but for lignites and other coals containing above 35 per cent. of volatile matter they are less accurate, being in excess of the truth. C. S.

CALORIMETER FOR DETERMINING THE HEATING VALUE OF COALS.

By R. C. CARPENTER, Professor at Sibley College, U.S.A. *Transactions of the American Society of Mechanical Engineers*, 1894-5, *vol. xvi.*, *page* 1040.

During the last year, a new form of coal calorimeter has been in use at Sibley College, U.S.A., consisting of a closed vessel surrounded with water. Combustion takes place in the vessel, and instead of measuring the rise in temperature of the water, its increase in volume is used to determine the heat evolved by the combustion of the coal. The combustion-chamber has a removable bottom, and the products of combustion are led off through a long spiral pipe immersed in the water. Compressed oxygen is introduced into the vessel through a pipe passing through the plug, and the latter, as in other calorimeters, also carries a small dish containing the coal to be tested. The charge is fired by electricity, the two wires passing through the bottom of the chamber.

The novelty of the instrument consists in the method used for ascertaining the rise in temperature of the water, simply by its increase in volume. The water vessel communicates with an open small glass tube, graduated to scale, the zero level in which is determined by an adjustable diaphragm. The height to which the water rises shows the heat developed by the combustion of the fuel. The instrument is so designed that combustion takes place practically at a constant pressure of 2 to 5 lbs., which has been found in practice to give the best results. No special appliance for stirring the water is required, nor is it necessary to allow for the heat of the instrument. The scale for marking the temperature is calibrated simply by burning different weights of pure carbon. For this purpose coke free from volatile substances is used, and allowance made for the ash produced. A calibration-curve is thus obtained, co-ordinating B.T.U. and weights of fuel. The original paper is illustrated by drawings. B. D.

OUTBURSTS OF CARBONIC ACID GAS.

(1) *Un Coup de Mine et de Gaz.* *By* EL. *Moniteur Industriel*, 1896, *vol. xxiii.*, *page* 381.

At Rochebelle, Gard, France, as in other collieries infested with carbonic acid, if there be constant and general disengagement, the gas is also stored up in large quantities, so that, while normally energetic ventilation can maintain a respirable atmosphere, a sudden invasion of the working-places is always to be feared, with the disturbance due to an escape of gas under great pressure. Everything, therefore, which procures for the gas a large issue should be carefully avoided, so that control be never lost over the ventilation; consequently, mine shots should never be employed in such a case, because, whatever be the explosive used, its sudden violence more or less shakes the surrounding rock, nearly always causing fractures that may, sometimes, be deep. Now, if one of these fissures should lead to a cavity filled

with gas, the latter will escape, and all the more rapidly if fracture of the rock should permit of the outlet being enlarged, leading to the complete and instantaneous invasion of the working-place, and perhaps of the whole district of workings. As most outbursts of carbonic acid have been brought about by shot-firing, it would only be logical to replace explosives by mechanical means, which are largely used at the Marihaye and Ouest de Mons collieries in Belgium. This repetition of cause, succeeded by its effect, does not, however, appear to drive its lesson home, because the last carbonic acid outburst at Rochebelle was also caused by the firing of a shot.* J. W. P.

---

(2) *Catástrofe de la Mina Serafina, de Cáceres.* ANON. *Revista Minera, Metalurgica y de Ingenieria*, 1896, *vol. xlvii.*, *page* 130.

A violent outburst of carbonic-acid gas took place at this mine on April 3rd, 1896. Two levels were being worked at 535 and 633 feet below the surface. A number of shots had just been fired, and the men who had been waiting for the kibble to bring them to bank had just given the signal to be drawn up. When it came up, there were only three men in it, fainting, and with their lights out. They said that the mine was full of choke-damp, and that their mates were killed by it. A foreman at once went down; but, at a depth of 330 feet, he encountered the damp, and had to come up again. As speedily as possible, 650 feet of steam pipe were put in position in the shaft, and steam at 60 lbs. pressure forced down. This drove up so heavy a column of carbonic acid gas that even the lights at the mouth of the shaft were extinguished; and it was not till April 14th that men were able to go down and recover the last of the bodies in the mine, four lives having been lost by the accident.

[La Serafina is described in the official mineral statistics of Spain as an argentiferous lead mine, and has been at work for many years.] H. L.

THE TRANSPORT THEORY OF COAL FORMATION.

Un Banc à troncs-debout aux Charbonnages du Grand-Bac, Selessin, Liége. By the REV. G. SCHMITZ. *Bulletin de l'Académie Royale de Belgique*, 1896, *vol. xxxi.*, *page* 260.

Partizans of the theory that coal was formed from plants on the spot where they flourished, instead of being brought from a distance, have always regarded as one of their best proofs the existence of upstanding tree-trunks in the roof of coal-seams; and, if this be the case with isolated stumps, what importance will not be attached to a large number of petrified trees in positions as near together as those they must have occupied when growing?

In November, 1895, the author found 33 stumps of tree-trunks in the roof of the grande-veine coal-seam in the Liége coal-field, where the seam, highly inclined to the south of the Seraing fault, is cut by a level at the depth of 1,342 feet (409 metres). Although upstanding trunks are not rare in the grande-veine, their frequent occurrence at the spot mentioned was remarkable. The seam being highly inclined, the smooth and brilliant surface of the roof permitted observation of the numerous circumferences which clearly defined the base of each trunk. These petrified cylindrical trunks had a carbonaceous sheath, sometimes 0·40 inch (1 centimetre) thick, which was nothing else than a portion of the tree turned into coal; and under this carbonaceous bark might be observed, on most of

* *Trans. Fed. Inst.*, vol v., page 564.

the trunks, the impressions of large ribs, which appeared to indicate that the tree belonged to the large *Sigillariaceæ* of the coal period. The 33 trunks were spaced over the northern wall of the level, which is 6½ feet high by 300 feet long, thus giving each tree a mean space of 60 square feet.

The presence of so large a number of upstanding tree-trunks appears at first sight to favour the idea of their being, as Prof. Grand'Eury expresses it, *in loco natali;* but two other circumstances are absolutely opposed to this view. The first is that the stumps are cut off sharply at right-angles as they near the coal-seam; and most of them show a very pronounced splaying-out, which is natural to tree-trunks near the springing of their roots. The second and more important circumstance is that, notwithstanding their slight thickness, the *lamellæ* of the false roof contain very varied prints, including those of numerous stalks of *Lycopodinaceæ* and *Equisetinaceæ*, flattened and in a horizontal position. Moreover, among these stalks, four adhere directly to the bases of four of the tree-trunks, and this so closely that their impressions pass like a secant across the base of the cylindrical trunk. The impression, well-defined both sides on the underlying and overlying rocks, is equally well defined on the very base of the trunk. It is, therefore, impossible to assert that these stumps occur in the place where they grew, and that they thrust forth their roots notwithstanding the stalks adhering to the surface of their cut-off base. Moreover, if this conclusion forces itself on the observer as regards these four trunks, it must also hold good for their 29 neighbours, which evidently owe their conservation to the same causes. The case here related can only be explained by the transport theory, the plants and sediments having either been transported in a mass; or a remarkable chance must have brought together these 33 standing trunks from their various *habitats*, through the agency of some mighty river. J. W. P.

THE FUSIBILITY AND COMPOSITION OF COAL-ASH.

Recherches sur les Relations existant entre le Degré de Fusibilité et la Composition des Cendres de Houille. By Eugène Prost. *Revue Universelle des Mines, etc.*, 1895, *vol. xxxi., page* 87.

The mineral constituents of coal are due to (1) the mineral substances forming part of the plants transformed into coal; (2) the mineral matters deposited at the same time as these plants; and (3) infiltrations into the coal-seams. But it is evident that all these substances are not found in their entirety, and without transformation, in the ash left by combustion. During incineration some mineral constituents are volatilized, and others decomposed or partially oxidized, while new combinations may be formed.

According to Dr. Muck*, coal-ash contains, or may contain, free silica, free oxides of iron and manganese, alumina, lime, magnesia, alkalies—the last five in the state of silicates the sulphates of iron, lime and baryta, carbonate of lime, carbonate of magnesia, the phosphates of iron and lime, sulphides of iron and lime, oxide of copper and titanic acid, of which the most important, as regards their action on the fusibility of ash, are evidently those present in tolerably large proportion, viz., silica, iron oxide, alumina, lime, magnesia, and the alkalies.

Most analyses of fuels are limited to the determination of humidity, volatile matters, yield in coke, sulphur, and ash-contents; and by means of these data, to which is sometimes added the more or less correct determination of the calorific

* *Über Steinkohlenasche*, 1878, page 4.

power, an attempt is made to designate the most appropriate use for a given coal. The composition of the ash is rarely taken into account; and yet this is of the greatest importance, because on the composition of the ash depends its degree of fusibility. A given coal, of theoretically higher calorific power than another, may give bad results in actual use, simply because its ash, too fusible for the temperature to which it has to be subjected, will obstruct the grate, interfere with the draught, and therefore render the combustion irregular.

The author has had occasion to examine and compare various samples of patent fuel which, although their ash content and calorific power differed but slightly, gave, some good and others bad results, when burnt on the fire-grates of boilers. His investigations on the relation between the fusibility and the composition of an ash bore upon twenty-three samples of coal and briquettes from the Liége and Charleroi districts of Belgium; and a description is given of the manner in which the tests were made, together with the ultimate chemical composition of the ash of each sample. The author's conclusions are as follow:—

The ashes examined are, after fusion, multiple silicates, essentially formed of alumina silicate, and subsidiarily of iron, lime, magnesia, and alkaline silicates.

The degree of fusibility chiefly depends on the ratio between the alumina and the silica on the one hand, and that of the other bases to alumina on the other. It diminishes when the alumina content increases, the content of bases diminishing; and conversely it increases when, for the same silica content, the bases increase in proportion to the alumina, at any rate up to a certain limit.

The least fusible ashes are those in which the alumina content is from 32 to 34 per cent., and that of silica from 46 to 50 per cent.

The increase of fusibility is more marked with a diminution of the alumina content than with an increase in the content of other bases, the proportion of silica remaining the same.

Oxide of iron exerts greater influence than lime on the degree of fusibility.

The fusing action of iron oxide, lime and magnesia only increases up to a certain limit; and when their proportion is too great, although infusible themselves, they act in the same manner as an increase in alumina content, *i.e.*, they diminish the fusibility of the ash. J. W. P.

ANTHRACITE IN THE PERMIAN ROCKS OF BOHEMIA, AUSTRIA.

Die Anthracitführende Permablagerung bei Budweis in Böhmen. *By* Dr. Fr. Katzer. *Oesterreichische Zeitschrift für Berg- und Hütten Wesen*, 1895, *vol. xliii., pages* 15 *and* 31.

There are two deposits of anthracite in the Permian system of Bohemia, one near Brandau in the Erzgebirge, the other in Southern Bohemia, near Budweis. The latter is the more important, but although its existence has been known for centuries, it has only recently been worked. The coal-bearing formation is 5¼ miles long by about 2 miles broad, and extends over an area of 5·8 square miles. It is surrounded by Archæan, and covered by Tertiary rocks. The Permian rocks in which the anthracite is embedded are divided by it into two formations, upper and lower, and are said to extend for some distance under the town of Budweis. The lower Permian strata, consisting of conglomerate, arkose, and sandstone, are best studied in the southern part of the district, where there are quarries, now disused, from which stone was formerly obtained for building. Where the rocks are thus exposed, the strata are not clearly defined, and the conglomerate appears to be irregularly intercalated in the sandstone. The latter is composed of fine quartz,

pebbles, felspar, and ferruginous sandstone. The arkose contains much mica, chiefly muscovite, which, with the felspar, gives it a granitic appearance. The same formation is found in the hills to the south-east of the mine. The sandstone here is rich in quartz and poor in felspar; it is coloured green by chlorite, and cemented with kaolin. It seems at first sight as if these sandstone-rocks, with alternate layers of conglomerate, formed the roof of the whole Budweis Permian system, but as they do not occur elsewhere their presence here is probably due to a fault and upheaval.

The upper division of the Budweis strata consists of the anthracite coal-seam, and above it of irregular layers of red and grey sandstone, rich in mica, sandstone, schist, and clay-slate containing fossils. In some places these rocks lie directly over the arkose and lower sandstone, and follow the line of outcrop of the coal. The sandstone forming the roof of the workings is so firm that no wood is required to support them. This upper coal-bearing stratum is found at a depth of about 260 feet, and is 60 feet thick, the seam of anthracite being in one place 3½ feet thick. Above, approaching to within 7 feet of the surface, are clay-slate and soft sandstone. A bore-hole passed through firm sandstone, clay-slate, and schist, and marl at a depth of 111 feet. Calcareous marl containing fish-scales was also found elsewhere in the roof of the seam. A little lower, at about 120 feet, clay-slate streaked with coal was reached.

It is the seam of anthracite which forms the most important and regular layer of this Permian system. The mine was discovered in 1560, but never opened out, because there was no market for the coal. At present only one shaft is worked, with galleries east and west, at intervals of about 50 feet. The coal stratum has a dip of about 30 degs., with one large fault, and is chiefly pure anthracite, with occasional mixture of clay-slate, and streaks of pyrites, containing silver; traces of this metal have been found in the ashes. A second shaft has been abandoned, because the workings approached an ammunition depôt. Both shafts showed that the coal was contained in a single seam, and not in two beds. The mine is very dry, water being seldom found, and pumping is only necessary at intervals.

The quality of the anthracite is excellent. It is almost pure throughout, with a metallic lustre and conchoidal fracture, varies in hardness, and its density at 19 degs. Cent. is about 1·5. Its chemical composition is not uniform. One sample gave 89 per cent. carbon, 3 per cent. hydrogen, 2 per cent. oxygen and nitrogen, and small percentages of sulphur, water, and ash, but the heating value and quantity of ash vary with the position in the seam of the sample tested. The percentage of ash is from 2·8 to 17·2, and heating value from 14,640 to 12,780 British thermal units.

Notwithstanding the differences of composition, the Budweis coal might be worked to much advantage, if the bed were more advantageously situated. The general lie of the strata is trough-shaped, the layers at both ends being flattened, but they are much disturbed, and sometimes so fissured that the stratification is quite obliterated. Here and there the Lower Permian formation comes to the surface, giving evidence of violent upheaval, and of an overlap fault running through the whole system, causing the older to overlie the later rocks. The northern part of the bed forms a fairly regular depression, having the main fault at the bottom. The seam of anthracite has only been traced on the western side of this depression, but it is probably continued to the east; elsewhere the formation is very irregular.

The mine lies high, and some of the workings are 1,360 feet above sea-level. The seam of anthracite scarcely ever follows a regular course, but crops up un-

expectedly in many places, doubtless as the result of a series of faults. For this reason the author considers that the workings should not be extended in the southern part of the mine, as owing to these frequent faults the coal-bearing formation is much dislocated and interspersed with sterile sections.

The tilting up of the strata is due to the upheaving forces at work throughout Bohemia in post-Permian times. Strong pressure was exerted in a south-easterly direction, crushing together the masses of gneiss, wedging the Permian rocks between them, and thus producing the great fault which runs across these mountains. Parallel with it is a whole system of fissures, and there are also cross fissures, caused partly by pressure and partly by folds. The effect is shown in the metamorphosis of the rocks, especially those containing fossil plants, and in the anthracite itself. It is strange that where so much disturbance has taken place the remains of plant life should be so well preserved.

It was proposed some years ago to bore 1,000 feet beyond the southern boundary of the mine. If anthracite were found here it would show a sub-Tertiary extension of the Permian system. Tertiary rocks have, it is true, been discovered resting on the Permian, and were in one place traversed to a depth of 129 feet before the Permian were reached, but no coal rewarded the search. The presence of gneiss rocks close by proved that the Permian had been placed by a fault in juxtaposition with the Archæan system. B. D.

THE SOUTHERN PORTION OF THE VALENCIENNES COAL-FIELD, FRANCE.

Note sur la Constitution du Midi du Bassin houiller de Valenciennes. *By* — CHAPUY. *Annales des Mines*, 1895, *vol. viii., page* 192.

The paper that appeared in the *Annales des Mines*,* by Prof. Bertrand, has drawn attention to the southern portion of the Valenciennes coal-field, by holding out the idea of the possible existence, to the south of the Anzin, Douchy, Azincourt, and Aniche collieries, of a band of Coal-measures, the width of which may attain about 3 miles, covered over by more ancient rocks. After examining the information afforded by the various bore-holes and mine-workings since the publication in 1886 of a work on the Valenciennes coal-field, by Mr. Olry, the author arrived at the following conclusions:—

The strike of the coal-seams in the Douai division of the Aniche colliery, and in Nos. 3, 4, and 5 pits of the Escarpelle colliery, with which the former correspond, and the characteristics of the disturbances which affect them, appear to show that the seams in the Aniche colliery to the south of the disturbed zone, which must have really caused a comparative downthrow of the southern portion of the basin, constitute one and the same group of seams, occupying the site where they were deposited, and that they must in no way be regarded as forming part of an overthrust fault.

To the west of the Aniche colliery, in that of Escarpelle, and beyond it in the Pas-de-Calais, a series of similar disturbances are found; and the existence of these large faults, marking out the basin longitudinally about its middle, and causing a relative downthrow of the southern portion, must be regarded as following a general law in the Nord and Pas-de-Calais coal-fields. Too great importance must not be attached to the absence, in the south of the basin as actually proved, of groups of semi-bituminous and non-bituminous seams, seeing that it appears to

* 1894. vol. v., page 569.

follow, from the facts ascertained up to the present time, that the deposits of bituminous coal rest to the south directly on the bottom of the basin, independently of any hypothesis as to the constitution of its northern edge.

At the other end of the northern basin, on the Belgian side, the workings of the Crespin colliery show that the Coal-measures really exist under a covering mass, which must extend for a certain distance to the south of the Quiévrechain shaft. It may be foreseen that bituminous coal-seams, corresponding with those existing in the Mons basin, and in the various concessions on the south of the Valenciennes coal-field, will be met with below the flaming coals worked in the Crespin colliery. On the other hand, it is scarcely probable that semi-bituminous and non-bituminous coal-seams will be found below those of bituminous coal. As to the absence in the Valenciennes coal-field of the seams found in Belgium above the Long-Terne series, that is explained by the hypothesis that they did not extend so far, or that they were washed away by erosion.

In conclusion, these various considerations lead to the belief that the covering over of the Coal-measures by a mass of ancient rocks only exists, so far as the Nord coal-field is concerned, in a region near the Belgian frontier, and that, in the greater portion of the basin, the southern edges in the state left by the successive erosions, is simply folded so as to dip towards the south. J. W. P.

GEOLOGY OF THE BAYER SHAFT AND ADJACENT PORTION OF THE PILSEN COAL-BASIN, BOHEMIA.

Die geologischen Verhältnisse des Bayer-Schachtes und des benachbarten Theiles der Pilsener Kohlenmulde. *By* K. A. Weithofer. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv., pages* 317, 331, 345, *and* 355, *with plates.*

Previous to the sinking of the Bayer shaft, only the outer fringe of the Pilsen coal-field had been tested, so that only the lower formations were penetrated. In the present case, the upper formations were traversed by the shaft, and were found to consist of an upper layer of dark bluish-grey shales about 600 feet in depth, enclosing a few beds of sandstone, and containing near the base an important coal-seam about 5 feet thick. The last 150 to 200 feet of this formation was much disturbed, the rock being pulverized by reason of an extensive fault. Below this again, the shaft passes through solid sandstone, with a few thin beds of shale, down to the bottom rock, which is encountered at a depth of 1,367 feet. From borings made in the vicinity of the shaft it would appear that a number of dislocations of the strata have taken place, since the bottom rock is between 2,000 and 2,300 feet below the surface on the eastern side, but rises suddenly to about half that depth a little further away, the cover rock there consisting solely of the grey sandstone. To the west of the shaft the surface-rock consists of red shales from 250 to 400 feet in depth (which also occur with red sandstones above the grey sandstone in the borings next the shaft on the eastern side) resting on some 920 feet of sandstone strata, near the bottom of which occur the two or three coal-seams that are worked throughout the district. Another boring to the south-east displays the most complete stratigraphical section of the district, the grey shale being covered by a second (upper) series of red sandstone.

The examination of the district was rendered difficult by the presence of considerable tracts of woodland and the obscuration of outcrops by the surface-soil, often of great depth, but in general the same four series seem to prevail.

The fundamental rock consists of Archæan phyllites, grey, red or green in colour, and forms the southern boundary of the field, the previous assumption that granite formed the boundary between Chotieschau and Tuschkau being incorrect. From the metamorphosed condition of the contiguous granite and shale exposed near Hradzen it is evident that the granite is the younger of the two. In the Austria shaft, a mass of diorite is encountered, which, from the manner of the deposition of the superincumbent coal-seams, must have been in position when the coal was formed, and from its shape must be regarded as a surface-deposit, and not as intrusive. It contains a workable vein of blende, lead glance, and calcite, running in a north-westerly direction.

The surface of the bottom rock is diversified, and the coal is for the most part deposited in the hollows, only the highest seams passing over the ridges without interruption.

The light grey sandstone resting on the phyllite and below the coal is of very variable magnitude, sometimes being almost *nil*, and at others (*e.g.*, in a boring east of the Bayer shaft) attaining a thickness of 426 feet. In places it is interspersed with shales. The overlying coal-seams also vary in thickness and distance apart. The three chief centres of working are (1) between Littitz and Lihn on the east of the basin, (2) around Montau on the southern border, and (3) from Nürschau to the western limit of the field. Above the coal is a series of pale grey sandstones, decreasing in thickness from 1,100 to 1,150 feet near Lihn, down to 330 feet and less a little south of Neudorf. The sand is cemented with kaolin, and contains in places thin layers of grey shale, interspersed with narrow bands of coal. The total thickness of the sandstone series ranges from 1,500 to 1,600 feet near the Hilf shaft (Lihn) to 459 feet near Dobrzan, increasing again in the south and to the west of the Bayer shaft to between 1,000 and 1,400 feet.

The lower red shale group is of much smaller dimensions than the preceding series, varying from 130 to 650 feet. It appears on the surface as a narrow strip running north and south from the Hilf shaft, past Dobrzan, and in another strip, about 2,600 feet in width, between two large faults to the west of the Bayer shaft, running thence northward into the Duborz forest. A third outcrop lies in an east and west direction to the north of Choteschau, the eastern extremity being continued into the same forest, and a fourth covers a wide space between Auherzen and Zwug, narrowing to the westward by Horikowitz, and, after trending to the north, turns westward again near Pieheischen, the bend being due to a wide flat ridge sloping away towards the south of the Ziegler and Humboldt shafts. It is uncertain whether another belt of similar shale running east and west between Nürschau and Weipernitz belongs to this group or the upper series of shale, the evidence obtained from different borings being contradictory.

The surface rock at the Bayer shaft belongs to the fourth group, a series of dark grey shales, here 650 feet thick and containing coal-seams near the base as well as at a somewhat higher level, the coal of the latter layers being, however, of poor quality. The formation also extended superficially to the north of Stich and Wasseraujezd, undergoing a modification beyond the latter village into highly kaolinic sandstone, and being worked in several places for its kaolin. A number of *Anearites* are found in this series, and a considerable variety of fossils were obtained from the several beds during the sinking of the Bayer shaft.

The outcrop narrows between Lihn and the Clara shaft, but widens out again in a westerly direction further north. To the west it is covered by the upper red shale group, which increases in thickness from the line of contact. In the western

half of the field it occupies the centre of the basin, and a small outcrop of the kaolinic sandstone is worked for kaolin in the extreme south-eastern corner of the field.

The highest formation, that of the upper red shale, is darker in colour than the lower red series, and crops out largely around Lihn and Rothanjezd, where it overlies the gray shale and kaolinic sandstone, attaining a thickness of some 460 feet in its western portion. It also appears as a small patch (covered by alluvium) south of the Bayer shaft, on the edge of the basin.

The field is divided into two main groups by a considerable dislocation, extending in a north-and-south direction eastward of Nürschau, Auherzen, and Zwug, and terminating at the southern rim of the basin, a little to the west of Lake Kastel.

The strata in the eastern half have a north-and-south strike, and dip to the west, the fundamental rock sloping gradually from the eastern edge, and the other strata resting, as a whole, concordantly upon it. In detail, however, the conformity is irregular, and a number of faults, some of them of considerable extent, are met with.

The western section is of more regular conformation, and forms a synclinal running east and west, the basin being symmetrical between Lossin and the Humboldt and Lazarus shafts. To the west of Choteschau the lower series no longer crop out, the upper groups successively running into the projecting edge of the phyllite.

The south-eastern part of this section is traversed by several post-Palæozoic faults, some of them having a throw of 2,300 feet, and cutting through the coal deposits.

Concerning the age of the coal-seams in the grey sandstone, the author is of opinion that their stratigraphical position and characteristics indicate their origin in the early period of the deposition of the Carboniferous formation, and that they should not be divided, as some authorities have asserted, between the Carboniferous and Permian systems. At Nürschau, the lowest seam is of black coal, and is covered by sandstone and shale, on which rests a seam of cannel covered by 650 to 800 feet of grey sandstone. To the south this cannel runs out, and the black coal becomes thinner. In the Austria shaft, near Mantau, there are only two workable seams, and the coal here lies mostly in the troughs formed by the undulations of the fundamental rock: the lower seam has a thickness of about 6½ feet, and extends to the edge of the basin, but the upper one runs out earlier. The latter is of good quality, the lower coal being ashy and inclined to be slaty. Borings in the centre of the basin have revealed workable seams corresponding to those of the Austria shaft, and the same conditions are met with near the Bayer shaft.

In the Littitz-Lihn district, the main coal-seam, 6 to 8 feet thick, becomes slaty towards the centre of the basin, and finally disappears, but on the east, at the Sulkow pit and beyond, it yields a good coal. Above the main coal-seam at the Maria and Matilda shafts are four upper seams of 2½ feet, 1 to 2½ feet, 1 to 1½ feet, and 1 to 2½ feet in thickness respectively. The main coal-seam runs out on the west, the next seam disappears at a short distance, and the upper three coalesce to form two at the Sulkow shaft, afterwards uniting to one at the Hilf shaft.

The upper layers of coal, in the dark grey shale overlying the lower red shale, though widespread, only occur in workable quantity to the east and south-east of the Bayer shaft, where the thickness of the three seams reaches from 5 to 6 feet. None of them, however, is of any extent, all quickly running out. C. S.

THE DONETZ COAL-FIELD, RUSSIA.

(1) *Le bassin du Donetz.* *By* PETAU DE MAULETTE. *Bulletin de la Société de l'Industrie Minérale*, 1894, *vol. xiii., page* 869.

The author brought back from the Donetz coal-field specimens of anthracite, very curious, from a mineralogical point of view, on account of the quartz filaments which traverse it in an always identical direction, corresponding with that of a fault with respect to the seam. As in this field the coal is generally bituminous, he explains the anthracitous nature of that in question by the faults themselves, and also by the geogenic movements that have distributed the coal in sub-basins, separated by sterile bands, which have a distinctly geometrical relation to one another. J. W. P.

---

(2) *L'Industrie charbonnière et sidérurgique de la Russie Méridionale.* *By* PAUL TRASENSTER. *Annuaire de l'Association des Ingénieurs de Liége*, 1896, *vol. ix., page* 125, *and Plates VII.-XI.*

The Donetz coal-field, the largest in Europe, extends over an area of about 11,532 square miles, being twenty-two times as large as the Belgian coal-field, and larger than all the British coal-fields together. Only a small portion of its southern edge reposes on the ancient rocks; but, for the rest of the surface the Coal-measures, dip under more recent rocks—Permian on the north-west, Cretaceous and Tertiary towards the river Donetz, the Dnieper, and the Sea of Azov. A few Carboniferous islands, in some of which working has been attempted, emerge from the Tertiary towards the east and also towards the west, showing that the coal-formation extends far beyond the limits of the main basin.

The Coal-measure zone is a region of high plateaux furrowed by streams, which flow towards the north into the river Donetz, and towards the south into the Sea of Azov. The railways generally follow the crest, which is but slightly undulated, thus saving the necessity of crossing ravines. There are no large towns, Jusovo, Jusovka, Bashmut, Lissichansk, and Lugansk being the most populous places, while the nearest towns of importance are Rostov, at the mouth of the river Don, Ekaterinoslav, on the river Dnieper, and Kharkov on the north, near the source of the river Donetz; and the neighbouring ports are Taganrog, Mariupol, on the Sea of Azov, and Novo-Cherkask, the capital of the Don Kossacks.

Recent explorations have shown that there are two horizons, or groups of seams, in the Donetz, as in other European coal-fields. The Lower Carboniferous, almost sterile, forms the southern edge, from which is detached a parallel band extending between Volintsevo and Suline-Grushevka, corresponding with a synclinal of upheaval. The remainder of the basin belongs to the Upper Carboniferous series, containing coal; and, according to Prof. Grand' Eury, it corresponds with the Middle Zone of the second phase of the Permo-Carboniferous period, thus showing the coal of the Donetz to be contemporaneous with that of the Franco-Belgian coal-field. The Coal-measures are naturally divided into two distinct portions, geologically identical, but very different as regards the quality of their coal-seams. The eastern portion, which comprises about two-thirds of the coal-field, only yields anthracite or anthracitous coals.

It is here, on the Voronèje-Rostov railway line, that working first attained any importance. Up to 1875, the production of anthracite exceeded that of coal; but now the Donetz coal-field produces nearly five times as much bituminous coal as it does anthracite. The principal centres of anthracite working are Grushevka, only

47½ miles from Rostov and Suline, the site of the Pastushov ironworks. The Grushevka anthracite only contains from 2 to 5 per cent. of volatile matter, the same proportion of ash, and from 0·6 to 2 per cent. of sulphur, occurring in seams about 3 feet thick. Increase of anthracite-consumption is hindered on the west by the competition of bituminous coal, and on the south and east by that of petroleum.

In the other portion of the coal-field, yielding coals of every description, the seams are much disturbed. On the southern side of the coal-field one finds a region of large and approximately horizontal seams dipping to the north, bearing east and west, and extending nearly to Ambrosievka in the anthracite region.

After a double undulation, the outcrops of the seams re-enter the Coal-measure zone near Volintsevo, where they are much inclined to the south-east; and, dipping sharply to the north, they surround, to a certain extent, the Permian gulf of Bashmut and the Carboniferous peninsula of Lissitchansk, where a much disturbed synclinal occurs, after which the seams again dip under the Cretaceous and Tertiary measures, watered by the river Donetz. The eastern portion of the coal-formation is constituted by three basins, according to Messrs. Nossov, who put the number of workable seams at forty-four, together measuring 120 feet of coal; but it is probable that there are only twenty really workable seams.

If the Donetz coal-field be very extensive, it is less rich than those of Western Europe as regards the number and distance apart of the seams and coal thickness, thus resembling the American coal-fields. In the Donetz, the coal thickness appears not to exceed 1 per cent. of the measures, against 3·2 per cent. in Belgium and 4 per cent. in Westphalia, with a mean distance between the seams of little less than 330 feet in the Donetz, against 100 feet in the Ruhr and Belgian coal-fields; but there are some richer groups, while it is not rare to meet with two seams only 66 feet apart.

As regards qualities of coal, in the western portion of the field adjoining the anthracite boundary, non-bituminous coals are worked, and then, in succession, short-flame semi-bituminous, long-flame semi-bituminous, and long-flame non-bituminous coals. The content of volatile matters, which may vary from 10 to 45 per cent., generally increases with the distance from the line separating the coals from the anthracites, and also with the height in the formation. J. W. P.

---

(3) *Kohlen-und Eisengewinnung in Süd-Russland.* *By* GUSTAV KRENKE. *Prometheus*, *vol. vii., pages* 321 *to* 325.

The chief coal-fields of Russia are those in the districts of Donetz, Ural, Moscow, and the Caucasus.

The Donetz coal-field, in Southern Russia, is by far the largest, extending between the river of the same name and the Sea of Azov, for a distance of about 160 miles, with a breadth of about 45 miles on the east, increasing to 70 miles in the western portion, and comprising an area greater than that of any other European coal-field. In addition to the coal and iron, constituting the chief mineral wealth of this district, it contains deposits of rock-salt, lead, zinc, copper, antimony, quicksilver, graphite, fine porcelain clay, alabaster, marble, and slate. The coal lies generally in parallel strata interspersed with slate and sand. There are about 300 seams varying individually from 2 to 7 feet in thickness. The coal-field may be divided into eight groups (1) the upper Donetz, containing 4 seams of a total thickness of about 13 feet; (2) the Bissitschaga-Balka group with 13 seams, totalling 30 feet in thickness, only 7 of which, however, are workable; (3) the Longani group, with 35 seams; (4) the Longantshik; (5) the Kamanka group;

(6) the Krasni-Küt; (7) the Forza Kalmius group, and (8) the lower Donetz group. The four last-named contain from 4 to 35 seams of a total thickness of 13 to 30 feet. Analyses of the coal from this district show it to contain from 16·60 to 69·15 of carbon, 41 to 30·28 of volatile matter, and 12·40 to 0·57 of ash, per cent.

In 1894, 127 pits were working and these gave a total output of about 3,300,000 tons, or an increase of 18 per cent. over 1893, there being, moreover, 11 more pits in operation than in the former year. There are, however, only 10 mines producing more than 100,000 tons per annum.

A fairly efficient railway-system provides for the distribution of the coal to Moscow, on the north; Taganrog on the Sea of Azov, and Rostov on the river Don, to the southwards; Nikolajew, Odessa, the Crimea, and Mariupol, at which latter place a harbour has been constructed for the purpose of providing an outlet for the Donetz coal to the Black Sea ports. The quays extend to a distance of about 4,000 feet along the harbour which is formed by two breakwaters, one rather over 5,000 feet long and the other about 1,500 feet in length, with an average depth of 14 feet. Loading is effected by the aid of a couple of hydraulic cranes.

In characteristics, the Donetz coals vary considerably. At Kurakowa, a close-burning coal is produced. The Rutshenko coals are in great estimation for forge work and locomotive firing. Similar coals are obtained at Kamenka, as well as good coking coal, and at Grushewka, anthracite. As a rule, the seams are regular and fairly horizontal, but thin. The anthracite is black, lustrous, and of high specific gravity; the close-burning coal is fairly resistant and has a dull fracture; the half-fat coal yields about 75 per cent. of coke; the fat coal is black, lustrous, pulverulent, and is used for forge work and for making coke for the smelting furnaces. The long-flame variety, which is burnt in hearth-furnaces, and also used for gas making, is hard and gives no dross. The long flame and dry coal is also hard, but gives out little heat, and meets with no demand.

The 3,300,000 tons produced in 1894 were distributed as follows:– Railway consumption, 29·50 per cent.; salt works, 1·50 per cent.; gasworks, 1·25 per cent.; steamships, 6·50 per cent.; smelting-furnaces, 23·75 per cent.; sugarworks, 10·25 per cent.; other industries and private use, 27·25 per cent.

Even more rapidly than the coal industry has the iron trade of South Russia developed within the last few years, the increase being fully tenfold (331,000 tons, as compared with 33,000 tons in 1883), or more than twice as much as in any of the other districts under the Imperial government. This is attributable to high protective duties, the development of the railway-system, and the plenitude of ore and coal in close proximity. Ore occurs in the Donetz coal-district, and at Krivoï-Rog, not more than 300 miles away, a particularly rich ore (60 per cent.) is found in large quantity, easily workable from the surface.

The first smelting-furnace was erected by Mr. John Hughes in 1871, near Jusowo, about 80 miles from Mariupol. At present there are five large furnaces at work, two more in course of erection, 12 Siemens-Martin furnaces and a rail-rolling mill at these works, and a Bessemer-steel furnace is projected. Twenty puddling-furnaces are worked, and a staff of 7,500 hands is employed, 5,000 being at the smelting-works, and the other 2,500 at the colliery.

Other large establishments in the district are those of Pastukov, the Iron Ore Company, the Briansk Company, the Dnieper smelting-works, and the Donetz iron and steelworks, in addition to numerous smaller concerns, and the number of works is constantly on the increase. C. S.

VILLANUEVA COAL-FIELD, SPAIN.

Fomento de las Minas de Carbon de Villanueva. ANON. *Revista Minera*, 1896, *vol. xlvii., pages* 19-20.

The possible extension of the Coal-measures of Villanueva del Rio, in the province of Seville, has for years been a question of much importance, seeing that there is every probability that, instead of its being confined to the very small basin now known, it may extend beneath the Tertiary formation to a considerable distance below the Guadalquivir, in the direction of Seville and Moron, although perhaps at a great depth. Several mining engineers have held the view that this basin may be not a very restricted one as it now appears to be, but is really of immense size, because of certain indications near Moron that might be taken for the outcrop of a basin with an area of a hundred or so square miles. The great expense of the necessary explorations and the risk attending it have prevented the capitalists and miners of the country from venturing upon them; on the other hand, the Madrid, Zaragoza, and Alicante Railway Company, the owner of one extremity of the basin, has, as a foreign concern, no interest in the prosperity of the country except so far as it regards its own direct benefit. It suits the company quite as well to produce a small amount of coal with a high profit as it would do to extract five times as much with one-fifth of the profit per ton, but for the country the possession of a larger amount of fuel at a lower price would be a great advantage. No one can blame a foreign company for acting selfishly, but rather the Andalusians deserve reproach for having neglected a matter that so greatly interests the country. The railway company after having secured all the known portion of the Villanueva basins has not forgotten to examine the question whether the coal-seams continue, and has explored a considerable distance towards the Guadalquivir without, however, going to excessive depths.

The explorations have been carried on with the utmost secrecy, and it has never been known to what depth or to what distance they extended. Now, however, a fact has come to light that indicates that coal-mining in this region will receive a considerable extension, seeing that a 300 horse-power horizontal compound winding-engine is being erected for the Villanueva coal-mines of the Madrid, Zaragoza, and Alicante Railway, and an engine of this size can only be intended for operations on a large scale. It is, however, doubtful whether there is any intention of raising the 600,000 or 800,000 tons a year, which might be got for supplying the demands of Seville, Huelva, and Cadiz, including Gibraltar, all of which could be met from this Guadalquivir coal-field. The new shaft, which will be No. 5, will be down in some twelve or fifteen months, and will be furnished with a 500 horse-power pumping-engine. The present centres of production will last until the new one is in full swing, and in the public interest it is to be hoped that it will turn out more than the 100,000 tons a year which are now being raised. H. L.

PUERTOLLAÑO COAL-FIELD, SPAIN.

La Cuenca Carbonifera de Puertollaño. By MANUEL SANCHEZ Y MASSIA. *Revista Minera*, 1896, *vol. xlvi., pages* 33-35.

The author has long believed that the Puertollaño coal-field extends beyond the limits of an imaginary oval that had been set down as its outline. The general opinion is that this field, whose surface shows no indication of disturbance, necessarily forms a perfectly-shaped basin between two hills of Silurian quartzite, the strata of which on the northern side dip to the south, and on the southern

side dip to the north; that the coal-seams had the same dips as the quartzites, maintained a uniform thickness and underwent no change over all the area. This assumption is however quite incorrect. The Marquis of Casa Loring sank a shaft in his concession in the south-western corner of the field, showing the following section, the strata appearing to dip 5 degrees to the south:—

	Feet.		Feet.
Basalt	12⅓	Broken ground	2
Alluvial	5	Shale	2
Carboniferous shale ...	6½	Broken ground	1½
Coal	¼	Shale	1¾
Shale	1	*Coal*	1½
Coal	7	Shale	4¾
Shaly sandstone	2¾		
Coal	2¼		50¾

Sixty feet to the north a second shaft was sunk, which cut the top seam of coal at 10 feet in depth. It would appear, therefore, that a very little further to the north the seams disappear and the theory of the oval basin would be confirmed; but still further north, in making a well, a coal-seam was cut, and this seam evidently continues with a northerly dip until it reaches a depth of 203 feet, at which it was proved by a bore-hole, so that the interruption in the Coal-measures, which has also been spoken of as their boundary-fault, is only a consequence of denudation which has cut away and destroyed in part at least the upper portion of an anticlinal which is clearly marked by the above dips. Other bore-holes to the north have also cut the coal-seams: one of these 115 feet deep cut two seams respectively 9½ and 5 feet thick; on sinking a shaft on the site of this bore-hole a heavy influx of water was met with in approaching the top seam which forced the sinking to be suspended. It may therefore be taken for granted that neither the imaginary oval outline nor the so-called boundary fault will prevent capital from being employed in opening up a coal-field that has the advantage of being only 124 miles from Madrid and some 60 miles from Linares and La Carolina, more especially now that the Marquis of Casa Loring is engaged in the construction of a railway-line that shall unite Linares and Puertollaño, with the object of carrying coals from the latter field to the former important mineral district. H. L.

COAL IN THE TRANSVAAL.

Terrain carbonifère du Transvaal. By M. Lapierre. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, *page* 59.

The rocks in the coal region are superposed in the following order:—(1) Primary (granite, gneiss, and siliceous schists). generally Silurian; (2) Devonian (quartzose sandstones, hardened clay, and auriferous conglomerates), disturbed by numerous eruptions of igneous rocks, which have caused frequent metamorphism, and have thrown the strata sometimes into a vertical position; and (3) the Karoo Beds (grey sandstone, black and blue-grey schists, coal, and white sandstone), in which but few fossils have been found, and which do not present the same appearance as the Coal-measures in other parts of South Africa. Some geologists have endeavoured to connect them with the Trias or Permian; but this opinion, based on insufficient evidence, is open to question.

The coal, impure, and containing from 20 to 25 per cent. of ash, is worked by leaving in the pillars. The seams are thick, and the roof is so strong that no timbering is required. The mean depth of the deposit is 150 feet. The coal is raised by rectangular shafts, divided by partitions parallel with the short side of

the rectangle, into four compartments, two for winding, one for the ladders, and the fourth for the steam and compressed-air pipes and electric cables. The coal raised is screened, the slack being tipped out to spoil, while the large cobbles and nuts are alone utilized. A colliery plant comprises a 40 or 50 horse-power winding-engine, a 20 to 30 horse-power engine for working the screens, and a special engine for working the dynamo. The working is very remunerative, the cost being from 5s. to 6s. per ton, and the selling price 9s. The Braakpan colliery, opened about six years ago, now produces 1,200 tons daily, and paid for the working year 1894-5 a dividend of £64,000 on a capital of £400,000. J. W. P.

ANCIENT COPPER MINES OF SINAI.

Sur les Mines de Cuivre du Sinaï, exploitées par les anciens Égyptiens. By PROF. BERTHELOT. *Comptes Rendus de l'Académie des Sciences*, 1896, *vol. cxxiii., pages* 365 *to* 374.

Specimens of ore, rock, scoriæ, and fragments of furnaces and implements, recently obtained by Mr. de Morgan from the ancient workings of the Wadi-Maghara and Serabil-el-Khadem beds of the Sinai mines have been examined by the author.

The cupriferous minerals consist of turquoises—of normal composition, occurring free and dispersed in the ferruginous sandstone,—a hydrosilicate of copper, and sandstones impregnated with copper salts (hydrosilicates and carbonates), probably resulting from the action of water on pyritic veins at greater depths. Some of the sandstones are ferruginous, and in these the copper salts envelop the cementing hæmatite, thus showing their more recent deposition.

The actual percentage of copper is low, and the labour of sorting the ore must have been immense.

Hæmatite is found in large fragments at Wadi-Maghara, and in a fibrous condition at Serabil, occurring likewise in veins in the rock and as a cementing material in the sandstone. In both localities, dioxide of manganese is found, in some cases associated with hæmatite.

Although no beds of chalk have been recognized in the district, fragments occur in some of the specimens examined and in the scoriæ and *débris* from the furnaces. From the presence of pieces of charcoal in various stages of carbonization, it is evident that the furnaces were heated by wood fuel, which must have been transported from a distance, but the alteration has been too great to enable the kind of wood to be determined.

The absence of mattes indicates that no pyrites was worked, and none is found in the minerals.

No fluxes, beyond the natural sandstone mixed with hæmatite, seem to have been used, and the irregularity of fusion manifested by the scoriæ points to imperfect methods of working.

Microscopical examination of the slags shows two chief classes, the more crystalline containing crystals of fayalite and octahedra of magnetite; the other is composed of augites, with occasionally magnetite and felspar, and contains chalk from calcareous gangues.

As far as can be decided from the fragments of the furnaces and crucibles still to be found on the spot, the former were built of local sandstone and the latter made of a quartzose sand rendered adherent by means of clay. Grains of rounded and partly fused sand are embedded in the fused fragments, and here and there crystals of rutile and zirconia are met with in association with anorthite and ferruginous pyroxenes, the whole being surrounded by a mass of colourless glass.

Three fragments of tools were discovered by Mr. de Morgan among the ruins of the miners' huts at Wadi-Maghara. The largest originally formed part of a pick, and is bevelled at the one end, which corresponds in shape with the striæ in the rock. The fragment is 1½ inches in length, about ⅝ inch thick, and ½ inch wide, tapering to ⅜ inch at the bevel. It had evidently been cast in a rough mould, and is composed of copper and arsenic—the presence of this latter substance (which must have been added purposely, no arsenic being found in the minerals, etc., in this locality) in the tools shows that the Egyptians must have understood its property of hardening copper.

A portion of a (non-arsenical and with but very little tin) bronze tool resembling a graver was also found, together with a 2 inches needle of copper—free from tin and with merely a slight amount of arsenic.

Two other needles, probably of Sinai copper, were obtained from an Egyptian tomb, one of them exhibiting a peculiarity of manufacture in that, instead of being solid, it has a longitudinal cavity in the centre.

After having been worked for some 40 centuries these mines were abandoned 3,000 years ago, on account of the poverty of the ore accessible to the workers, and probably also by reason of difficulties of working and transport in such a remote region. It is interesting to note that in the course of their labours these early miners arrived at the same empirical processes that have continued down to our own time. C. S.

NEEDLE WEIRS.

Etanchement des Barrages au moyen de la Cendre d'usines, de Sable ou de Gravier. ANON. *Moniteur Industriel, Jan. 18th,* 1896, *page* 40.

Mr. H. Tavernier has pointed out the useful properties of smiths' ashes for making needle weirs tight. The weeds and small branches must be removed from the needles, which should be closed as tightly together as possible ; and then the ashes are introduced in front of them by a shovel or scoop. A boat, carrying the necessary quantity of ashes, is brought in front of the weir as the needles are made tight, the ashes being borne against them by the current. For this work three men are amply sufficient, one to manage the boat, another to throw in the ashes, and the third, on the foot-bridge, to point out where the ashes should be thrown. According to the size of the spaces to be stopped, the ashes are taken from the bottom of the heap, where they are large, or from the top, where they are finer. This method gives a thoroughly tight stopping to needle weirs ; and the stopping lasts from 10 to 15 days, after which it must be renewed wholly or partially. Although as tight a stopping may be made with sand or fine gravel, the quantity required is larger while the tightness does not last so long. J. W. P.

ELECTRIC POWER-TRANSMISSION IN MINES.

(1) *Einige Abbildungen und Bemerkungen zur elektrischen Kraftübertragung im Bergbau. By* C. KÖTTGEN. *Glückauf,* 1896, *vol. xxxi., page* 372, *and illustrations.*

The examples of a sinking-pump, a centrifugal pump on wheels, an hauling engine, electric motor for endless chain-haulage, electric locomotives, and electrically-worked percussive and rotary drills, bring prominently forward the two most important features of electric power-transmission. The first is, that it is possible to lead the current to any desired point in a mine without any considerable loss, or troublesome disturbance of the work through laying the conductors ; and the

second, that the great flexibility in the conductors, required for leading the current to the electro-motors, permits of the driven machines being moved from place to place without requiring any great care or preparation. The above-named applications show that electric energy for driving may be led to the very confines of a mine; but, if it be desired to keep down the cost of production, mechanical working must first be adopted.

The advantage of power being always available at any point may, in some cases, introduce considerable modifications in the getting of coal. It has hitherto been the rule to lay out the workings so that all the working-faces be situated at a higher level than the landing in the shaft, in which case the coal and also the water can gravitate to the shaft without any mechanical power being required; and such methods are still generally employed. In cases, however, where the exploring drifts reveal unexpected irregularities in the stratification, it often became necessary to undertake difficult and costly works at a lower level, upsetting the existing winding arrangements. Now, however, such works are unnecessary, as the working follows up the deposit closely; and, if the gradients should be so great that they cannot be mounted by man or horse-power, electric locomotives, or chain or rope haulage, electrically driven, are employed. If there should be a disturbance in the strata, and the seams be thrown down a few hundred feet, it is no longer necessary to deepen the main shaft and open the low-lying portion by a new level; but a staple pit should rather be sunk at the desired spot, and the winding and pumping effected by electric driving. J. W. P.

---

(2) *Anwendung der Elektricität im Bergbau.* ANON. *Glückauf*, 1896, *vol.* xxxi., *page* 622.

The largest pumps driven electrically that have yet been constructed are being erected at the Kübeck shaft, Anina, Hungary. The plant consists of two 3-ram pumps, each of which is designed to raise 176 gallons of water per minute, to a height of 787 feet, driven by two electromotors, each of 60 horse-power, making 550 revolutions per minute.

At the mines of the Upper Hungarian Mining and Ironworks Company, Szomolnokhuta, an electrically-driven duplex-pump is being erected for raising 154 gallons per minute to a height of 328 feet. Special interest is attached to this plant because of the metallic composition of which the rams and suction pipes are cast, and the fact of the cast-iron delivery pipes being lined with asphalt, on account of the very acid water.

The generating station for driving the pumps and a screen, as well as for lighting, comprises a horizontal high-pressure turbine, coupled directly with a 50 kilowatts dynamo, making 650 revolutions per minute. J. W. P.

---

(3) *Electric Power for Mining.* ANON. *The Engineering and Mining Journal (New York)*, 1896, *vol.* lxi., *page* 304.

In 1891, the San Miguel Consolidated Gold Mining Company decided to erect an alternating-current electric transmission-plant. The San Miguel Company owned gold-mines in the south-western Colorado mountains, where, owing to the high price of fuel and the altitude of 13,000 feet above sea-level, working had been found almost impracticable. The use of electric power was suggested, as the company owned an extensive waterfall in the San Miguel valley.

It was decided to adopt the Tesla polyphase system of electric power transmission, and a 100 horse-power alternating-current generator and a 100 horse-power motor, with the necessary switchboard appliances, were installed. The generator was connected with a Pelton water-wheel, and the current was carried for 3 miles up the mountains to the Gold King mine. The second installation comprises two 800 horse-power 500 volts quarterphase generators, running at 7,200 alternations. These generators will be directly connected to two Pelton water-wheels, and two 30 horse-power multipolar generators will be operated as exciters. These appliances are installed in the central power-house, and there are a number of sub-stations at the different mines throughout the property. Among these stations are distributed twelve 50 horse-power polyphase Tesla motors; fifteen 20 horse-power Tesla motors; twelve 100 kilowatts, one hundred 11,600 volts, two threephase step-up transformers; ten 50 kilowatts, 10,000 to 220 volts; ten 25 kilowatts, 10,000 to 220 volts, and sixteen 10 kilowatts, 1,000 to 220 volts, step-down transformers. The motors are attached, either by belt or direct-connected, to operate stamps, pans, hoists, crushers, elevators, or pumps.

J. W.

(4) *Note sur un Transport de Force par l'Électricité au Siége No. 5 des Mines de Marles, Pas-de-Calais. By* — BAILY. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, *page* 41.

At the No. 5 pit, a 500 horse-power compound condensing engine drives two dynamos, each of 80,000 watts, making 350 revolutions per minute, room being left for two others. In addition to sending current to No. 3 pit, 3,000 feet distant, power is furnished for hauling the coal from the working-places to the shaft at Nos. 3 and 5 pits, each of which produces 1,200 tons daily; for raising, by means of an electric winding-engine, to the 700 feet level the rubbish excavated in No. 5 pit, and hauling it by locomotives to the working-places, for gobbing a seam 6 feet thick. The conductors in the shaft consist of armoured copper cables, 1 inch in diameter and of 0·62 square inch in sectional area, which easily pass a current of 640 ampères, and in the levels by rails, weighing 17 lbs. per yard, on which run the trolleys.

Each of the new locomotives, which weigh 3·2 tons, is driven by a Gramme-wound dynamo, making 1,000 revolutions per minute; and its shaft, parallel with the rails, carries a mitre-pinion driving two others, naturally revolving in opposite directions, one for forward and the other for backward-gear. These two last-named pinions are loose on sleeves, keyed upon a transverse shaft, carrying the pinion which works into the spur-wheels fastened upon the axles. Motion is communicated to the sleeves, and consequently to the transverse shaft, by cast-iron rings, which, tightened by a wedge worked by the reversing hand-wheel, clamp the mitre-pinion on the sleeve.

With this arrangement the armature may be put in motion before starting, so as to utilize the *vis viva*, full current being afterwards given. The driver, on the front foot-plate, has at his command a lever for breaking the circuit, another for applying current, regulating and shutting it off, a hand-wheel acting on the reversing-gear, another working a screw-brake, and a handle for applying sand to the rails when required on starting.

The locomotive, which receives current at 500 volts, effects the work of fifteen horses, drawing a set of thirty tubs, each containing ½ ton of coal, at the mean speed of 8¾ miles, and maximum speed of nearly 10 miles per hour, each locomotive absorbing under these conditions from 35 to 38 ampères at 500 volts.

J. W. P.

GAS AND PETROLEUM MOTORS.

Les Moteurs à gaz et à pétrole à l'Exposition d'Anvers, 1894. *By* C. LAMBOTTE. *Annuaire de l'Association des Ingénieurs de Liége*, 1895, *vol. viii.*, *page* 169.

Including interest on capital, sinking fund, maintenance, supervision, cleaning, lubrication, and consumption, for a force of 2 horse-power effective, the gas-engine costs 2d.; the petroleum motor, 1·7d.; and the steam-engine, 2·8d. per effective horse-power. For a force of 10 horse-power effective, the gas-engine costs 1d.; the petroleum motor, 0·9d.; and the steam-engine, 1d. per effective horse-power. And, for a force of 50 horse-power, a gas-engine working with poor gas, and a condensing steam-engine, with steam-jacket and expansion variable by the governor, both cost 0·5d. per effective horse-power per hour.

The petroleum motor is, therefore, the most economical motor up to 10 horse-power, a force for which the cost of the horse-hour is appreciably the same with gas, steam, and petroleum; but above this power the steam-engine is the most economical, at any rate for continuous working of long duration, under which circumstances the user of a gas-engine must make his own gas. For a force of 50 horse-power, the cost of a day's work is the same with gas made from coke as it is with steam; but in the neighbourhood of anthracite-mines the advantage will be in favour of the gas-motor, which only consumes 1·32 lbs. of anthracite per effective horse-power, while the steam-engine consumes 3·3 lbs. of coal.

If steam and gas were found in a natural state, the steam-engine and the gas-motor working with lighting-gas would be the most economical; but, to examine the question practically, the coal burnt in steam-boilers and that for making gas must be taken into consideration. While the coefficient of utilization by the gas-motor is 17 per cent., there is only a real utilization of 6 per cent.; but, practically, the difference is not a dead loss in large installations, because of the set-off afforded by the bye-products. The combustion of coal for firing steam-boilers is in no better case, because, if the coefficient be 17 per cent. for the steam-engine alone, it is only 8 per cent. for engine and boiler together, while in this case there are no bye-products. Gas-producers give better results, as might be expected, the transformations of energy being fewer; and this number is also slight in the petroleum motor, which explains its high yield.

It may be concluded that the gas-engine has the highest economical coefficient: and it is susceptible of improvement—seeing that its theoretical yield is 38 per cent. by ameliorations in the cycle of the motor and of the gas-producers which are intimately connected with it. J. W. P.

ADVANTAGES OF COMPRESSED AIR.

Note sur l'Emploi de l'Air Comprimé. *By* — MORTIER. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1895, *page* 137.

Two very marked tendencies are now manifested in the working of mines. On the one hand, compressed-air plants are becoming more general, on account of the undoubted facility which they afford for carrying out works; and, on the other, endeavours are being made to substitute for compressed air, in the same applications, a more economical agent, such as electricity.

The author deals in turn with the imperfection of compressed air as an agent for transmitting power, its original yield or useful effect, the loss of pressure, and therefore of power during transmission, the compounding of compressors and motors, the general useful effect, and the influence of heat, arriving at the following conclusions: -

1. Compressed air, regarded as a transmitter of power, is just what it is made, its value being that of the mechanical and calorific conditions which are present at its production and utilization.

2. By the use of high adiabatic compression (those at constant pressure), rendering illusory any effective expansion, only an insignificant useful effect is obtained.

3. By the adoption of low pressures, this inherent defect is eliminated, but the dimensions of the pipes and the appliances are so great as to render them prohibitive.

4. On the other hand, by adopting successive compressions, even adiabatic, and especially a mutual compounding between motors sufficiently far apart for the air, partially expanded, to reacquire the surrounding temperature in passing from one motor to another, a useful effect of 50 per cent. may easily be obtained, and that with pipes and cylinders of moderate size.

5. The available energy transmitted by compressed air may be increased by heat in proportion to the binomial of expansion itself. While the other agents of power-transmission, water under pressure and electricity for instance, correspond with a thoroughly defined disposability of energy; compressed air, in addition to the amount of work it is capable of giving out adiabatically at the surrounding temperature, carries with it a credit, theoretically unlimited, for transforming into work any artificial heat which may be communicated to it; and this transformation is effected with so high a thermic yield that the supplementary work performed is obtained almost gratuitously.

In other words, a given weight of compressed air acquires, without appreciable complication and with an insignificant expenditure of fuel, an artificial quantum of energy at least equal to the natural energy which it furnishes directly; and this special faculty, added to absolute elasticity of speed, as regards both compressors and motors, and to the possibility of regulation or storage, is a characteristic of great importance, which will often justify preference being given to compressed air over other agents for the transmission of power. J. W. P.

THE LAVAL STEAM-TURBINE.

Note sur la Turbine de Laval. By A. Stévart. *Annuaire de l'Association des Ingénieurs de Liége*, 1896, *vol. ix., page* 33.

The Laval motor has caused great interest through the novelty of the principle on which its working depends, and the skill with which the great difficulties due to speeds attaining 500 revolutions per second have been surmounted. The steam does not act by its pressure, but is expanded, before reaching the wheel, to a pressure very little higher than that of the discharge, thus converting into *vis viva* all the calorific energy which it contains.

The enormous speed with which the steam impinges upon the vanes of the wheel obliges the latter to revolve very rapidly, the tip speed being about 0·4 of the steam's theoretical speed at admission. The turbine, actuated in this manner, may be regarded as an axial wheel with free deviation, and be treated like the receiver of the Euler turbine for determining the value of its principal elements and the conditions to be fulfilled for obtaining a maximum useful effect. The angle made by the entrance-surface of the wheel and the steam-jet should be as slight as possible; in practice it is not less than 20 degs., though this may possibly be reduced by abandoning the axial arrangement and admitting the steam by the outer circumference of the wheel.

The critical speed of rotation is that which gives a revolution in the same space of time as the spindle would make a double oscillation under the weight of the turbine ; and it is advisable that in practice the number of revolutions correspond with from one and a half times to twice the critical speed for dispelling all appreciable vibration.

The great speed is a weak point which leads to difficulties of various kinds and firstly, in the gear for transmitting motion, of little consequence with dynamo or other rapidly revolving appliances, but considerable in other cases, especially when the applications require greater power with comparatively low speed Secondly, the centrifugal force set up by this rapid rotation tends to burst the wheel at its periphery, where it is found necessary to attach the vanes to steel hoops as strong as possible ; and lastly, as it is practically very difficult to exactly balance such a wheel, and even slight eccentricity may greatly strain the spindle there is danger of breakage or at any rate of untrue running.

To the first and second of these difficulties the only remedy appears to consist in obtaining the same useful effect with a lower speed ; and the author suggests the use of a fluid denser than steam—a mixture of steam and compressed air, for instance. For the third difficulty a radical remedy has been found, which experience shows to be quite effective. The steel spindle is only from 0·3 to 0·6 inch in diameter ; and it is precisely this slight diameter, and the consequent flexibility which permits the revolving disc to move almost as if it were free, it being well known that the rotation of a free body has a tendency to take place round one of the principal axes of inertia passing through the centre of gravity, which remains fixed, if not influenced by an extraneous force. J. W. P.

EXPANSION IN WINDING-ENGINES.*

Note sur l'Emploi de la Détente dans la Machine d'extraction du Puits du Treuil No. 2 de la Société Anonyme des Houillères de Saint-Etienne. *By* — BERNE *Bulletin de la Société de l'Industrie Minérale*, 1896, *vol. x., page* 61.

The winding engine at the No. 2 Treuil pit was designed to raise 800 tons from a depth of 1,968 feet in eight hours. When winding coal, the moments are: at the start of the loaded cage from the bottom, 47,738 foot-pounds ; at the meeting of the cages, 54,972 foot-pounds ; and on the loaded cage coming to bank, 62,566 foot pounds. The engine is, therefore, practically balanced ; and the moment at the end of the lift is greater than that corresponding with the start from the bottom which is very favourable to safety and expansive working under good conditions so that the use of expansion, variable by the governor, is amply justified in the present case.

The arrangement of the governor acting on the expansion-gear, through the steam starting gear, has a threefold advantage, which is difficult to secure by the use of an ordinary governor:—(1) It affords a considerable amount of power for working the expansion-gear, which might become difficult through a too tight packing of the glands, or imperfect lubrication of the expansion-slides ; and (2) slight vertical movement of the governor, corresponding with a slight variation in speed, may give a considerable amount of travel to the expansion-valve, so that the steam may be expanded only when a certain determined speed is attained thus almost instantly securing the minimum admission. The parts in motion are small in the slight governor necessary for working the steam starting-gear, so that there is no fear of breakage in any part for transmitting motion to the governor, case the engine should stop suddenly.

* *Trans. Fed. Inst.*, vol. xi., page 213.

Comparative trials for ascertaining the coal-and-water consumption were made, both with and without expansion, during twelve and six working days respectively, when coal was wound from the thirteenth level 2,034 feet, and from the eleventh 1,627 feet, below the pit-bank, with four tubs from the former and two from the latter, or *vice versâ*, involving a work of 2,421,659 foot-pounds and 1,937,327 foot-pounds for each tub respectively; and also when water was being raised in buckets, each of which represents a work of 17,041,256 foot-pounds. Leaving out of the question the lifts, practically of equal importance, for purposes other than those named above, and putting the work performed in round numbers, it was found that, as regards water-consumption, the ratio of the useful effect with and without expansion was 0·685, showing an economy of 31·5 per cent. in favour of expansion. As regards the coal-consumption, the ratio of useful effect without and with expansion was 0·648, showing a fuel saving of 35·2 per cent. in favour of expansion. Nor was the saving negligible that was effected in lubricating the steam-cylinders when working expansively, on account of the smaller quantity of steam consumed.

Moreover, an examination of the diagrams, especially those bearing upon the first eleven revolutions, corresponding with the rising of the cage from No. 13 to No. 11 level, shows that with expansive working the throttle-valve was kept wide open during 7 revolutions, and only closed, and the reversing-gear employed, during the 4 subsequent revolutions; while, on the contrary, without expansion, the throttle-valve was only open during the first 4 revolutions, but partially closed, and the reversing gear brought into play, during the 7 following. In fact, with expansive working the throttle-valve remained wide-open during almost the whole lift, the governor alone reducing the steam admission by increasing the expansion; but, while working with full admission, the engine only maintained its normal speed when the steam was throttled by the shut off or by the reversing-valve, the consequent loss of load considerably reducing the useful effect of a given weight of steam.

These trials confirm the possibility of obtaining, by expansion-gear variable by the governor, the economical working of a winding-engine much too powerful for its normal work, but whose maximum power may be indispensable under certain circumstances. J. W. P.

EXPLOSION AT THE HOHENEGGER SHAFT, KARWIN.

Die Grubenkatastrophe im erzherzoglich Friedrich'schen Hoheneggер-Schachte zu Karwin am 16 *März*, 1895. *By* JOSEF BÖHM. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv., pages* 409 *and* 429.

The Hohenegger pit has two shafts, 167 feet apart, one for winding and pumping and the second for ventilating purposes. There are three main levels, at depths of 460, 560, and 690 feet respectively, the latter serving as a hauling roadway and the two former for ventilation. Direct communication between the shafts exists only in the middle level. Six coal-seams are worked, ranging from 3 to 5 feet in thickness, all of which are dusty and fiery. A Pelzer ventilator, with an average speed of 184 revolutions and capacity of 92,000 cubic feet of air per minute, induced ventilation by exhausting the air in the ventilating-shaft. For lighting, Wolf benzine safety-lamps, with double wire gauzes, are employed, and are tested regularly. Explosives are used only in extending stone-drifts, none being employed at all in working the coal, and the blasting material—dynamite No. 1, with electrical fuzes—is stored above ground, except the quantity taken down by the foreman.

To minimize the risk of coal-dust explosions, the dusty places are sprinkled with water from time to time, and at the date of the accident a permanent installation for this purpose was in course of erection in the winding-shaft.

The miners work in two 8 hours shifts, no operations, other than the execution of necessary repairs, being carried on between 10 p.m. and 6 a.m. Out of a total staff of about 300 men per shift, only thirty are engaged in the workings at night.

At 7·40 a.m. on Saturday, March 16, 1895, the shock of an explosion was felt; smoke and dust ascended from the winding shaft, and directly afterwards also from the ventilating-shaft. The winding-shed—an iron building 57 feet square—was lifted bodily from the ground, but fell back into its original position; the iron-plate floor of the pumping engine-house was destroyed; and other damage done around the mouth of the shaft. Below ground, however, no damage was done in the shaft down to a depth of 530 feet, except that three men working on a hanging platform, 98 feet from bank, were precipitated into the sump and killed. One cage (ascending) stuck fast at 535 feet, and the passage-ways below were destroyed. The ventilating-shaft suffered less, the only result of the accident being to cause one of the ventilator-bearings to run hot, without, however, impairing the normal efficiency of the machine.

The explosion caused the death of fifty-two men and six horses in the workings, in addition to severely injuring sixteen men, but its other effects were comparatively slight, being confined to two large and three small falls, and the destruction of, or damage to, the air-doors and bratticing.

From the duration of the escape of smoke *via* the ventilator, it was at first feared that the pit had taken fire. A rescue party managed to descend to the main ventilating-level, and, by repairing the broken doors, prevented the short-circuiting of the air-current to the upcast shaft. Most of the miners, meanwhile, had made their way up to bank by the passage-ways in the shaft, climbing up the shaft-timbers below the suspended cage, which fortunately could not be released for some little time, or its descent would have proved fatal to those escaping in this manner.

The upper seams (Johann and Carl-Roman) were first visited, the second level of these seams being, according to the miners, the nearest to the seat of the explosion. It was there found that the accident originated in a chamber used as a store, and as a resting-place for the foreman blaster when not engaged at his work. In this room the cartridge-box was stored, and at the time of the accident there were eighty long and forty short cartridges of dynamite No. 1, and thirty-four electrical band-fuzes there. The man on duty that morning had been observed thawing a frozen cartridge at his lamp, the usual jacketed thawing-pan having been sent to the repairing-shop. He was cautioned about the danger, but it is surmised that he continued to warm the cartridge until the paraffined paper case caught fire, whereupon he must have fled, his dead body being found in the gallery outside the store-room, only slightly injured. Altogether seventy-one long and twenty short cartridges of an aggregate weight of 15¼ pounds were exploded. The force of the explosion pulverized a portion of the adjacent coal, and the flame was communicated along the dusty gallery both east and west, the hot gases penetrating into the working-places westward and there killing thirteen men. Passing eastward, against the air-current, the explosion traversed the loop in the hauling-way, and through the loading-place, branched into the south-eastern roadway, where it ceased at some 720 feet from the shaft. It also penetrated into the Carl-Roman coal-seam, there following, with undiminished energy, the direction

of the air-current mainly in a westerly direction, and causing the death of the thirty men engaged in the western part of the workings. Another section of the Roman seam to the east of the ventilating-shaft was also affected, four bodies being found, and three men injured, one of whom died during his removal to the shaft.

The entire space affected by the explosion amounted to about one-third of the whole pit, and the deaths to 60 per cent. of the men employed within the zone of the disaster, or 18 per cent. of the whole staff in the shift.

The direction traversed by the explosion was indicated by the accumulations of ash and coke on the uprights, the former from fully-burnt dust, and the latter resulting from a slower action of the flame, as would appear from its occurring chiefly at crossings and in open spaces. An examination of the dust embedded on the vertical timbers showed it to consist of some 33½ per cent. of ash as compared with 18¾ per cent. of the normal coal-dust in the pit, a loss of about 7 per cent. of volatile matter being being recorded at the same time. The explosive nature of this dust was shown by some experiments carried out at the testing-station of the Ferdinands-Nordbahn at Mährisch-Ostrau, where 25 ounces of dynamite exploded in presence of 4·4 lbs. of this coal-dust produced a violent explosion, accompanied by a strong flame about 65 feet in length. This experiment sufficiently explains the extent of the accident of March 16th. Moreover, the composition of the air of the pit in the fortnight preceding the accident precluded the possibility of fire-damp having played any chief part therein, an opinion deriving additional confirmation from the fact that only one shock, that of the dynamite explosion, was felt.

C. S.

DETONATORS FOR EXPLOSIVES.

Zur Verhütung von Schlagwetter-und Kohlenstaub Explosionen. *By* M. Rückgaber. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, *vol. xliii., page* 53.

The author bases his remarks upon Mr. Lamprecht's paper on the prevention of explosions in mines,* but he confines himself to a consideration of the various methods of ignition employed in blasting. Of these there are two kinds, external and central. To fire the fuze from the centre by means of an electric wire is a method long in use among mining engineers, but it is not much in favour, on account of the cost, frequent miss-fires, and the sparks generated in mines containing fire-damp, which can only be avoided by great care in laying the wires. If the Lauer method of ignition by friction be substituted for central electric ignition, these difficulties are, to a certain extent, overcome, but the process is open to danger, due to manipulation and wear, and has not hitherto been much used. The stricter and more comprehensive the regulations for the traffic in explosives, the greater is the danger of an accident, if they be set aside.

The Tirmann percussion-fuze is another attempt to replace electric ignition by a safe and economical method of central firing. In it the capsule is separated from the igniter, and thus there is no danger in transport, as with the Lauer fuze. The author himself saw several thousand shots fired at the Fohnsdorff mines in Upper Austria with the Tirmann fuze, and not a single accident occurred. Out of 1,998 shots, there were only twelve miss-fires, and 400 shots were fired in succession without a failure. Apparently the greatest objection to the Tirmann system is that a miss-fire might cause an accident, because if the percussion-pin were wedged it might, while one is trying to extract it, become loosened. This cannot happen with the Lauer fuze, nor is it likely with the Tirmann, because of the smooth inner

* *Trans. Fed. Inst.*, vol. x., page 552.

surface and peculiar shape of the pin. When this fuse was introduced in 1894 it did occasionally miss-fire, but it was always possible to withdraw it carefully in the usual way, and no irregular explosions took place. The rounded crook and weakening of the end of the fuse, which caused the mischief, have now been improved, and the danger described by Mr. Lamprecht does not exist. Even now, before its superiority has been established by repeated experiments, the author considers this fuse better than others. Miss-fires are a disagreeable accompaniment of every method of firing, and the Bickford quick match itself, although so famous, shows a higher percentage than the Tirmann. The separation of the capsule from the fuse gives it an advantage over the Lauer, and it must be regarded as a distinct step in advance, as compared with other explosives. B. D.

DANGERS OF BLASTING IN FIERY MINES.

Die Bestrebungen zur Verminderung der Gefahren der Sprengarbeit in Gruben mit schlagenden Wettern. By FRANZ BRZEZOWSKI. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv., pages* 1-4.

The chief progress in this direction is to be looked for in the employment of good central-fire fuses and safety-explosives. To the former class belong the electric fuses actuated by currents too weak to ignite fire-damp; the Tirmann percussion-detonater, which has a record of only 0·2 per cent. of miss-fires from 400,000 shots, the improved Lauer friction-detonator and the new lime-detonator with water-cartridge, recently introduced by Mr. Jaroljmek. These allow the charge to be fired without risk of communicating flame to the surrounding fire-damp.

More difficult to prevent is the ignition of the fire-damp by the explosive charge itself. The danger may be diminished by employing an explosive charge not too powerful for the work which it has to perform (so that all the evolved heat may be used up as work); by restricting the diameter of the bore-hole to correspond with the cartridge; by the method of packing the cartridge—in this connexion celluloid parchment-paper, asbestos paper, or paper soaked in water-glass may be characterized as good, paper impregnated with ceresine being, on the other hand, bad—and by selecting the detonator with due regard to the charge to be exploded. Here, it has been shown that whilst a 17·64 ounces charge of westfalit exploded by a 15·43 grains detonator did not ignite a 7 per cent. mixture of fire-damp and air, a 10·58 ounces charge fired by a 46·23 grains detonator causes an explosion of the same gaseous mixture. The method of tamping, too, as shown by the photographs taken by Mr. Siersch,* affects the safety of the shot, moss acting particularly well in this respect.

Safety-explosives, generally, consist of ammonium nitrate (up to 96 per cent.) along with aromatic hydrocarbons (benzole, naphthaline, aniline) or nitro-compounds of these, as well as resin or fat. Their safety consists in an insusceptibility to explosion by flame or shock, since neither handling with tongs of red-hot iron, nor exposure to the hydrogen-blowpipe flame does more than cause them to fuse and burn away with a short flame, a strong blasting detonator being required to ignite them. They have the advantage over dynamite of not becoming so readily frozen. Their explosibility varies inversely with their density: for example, neither a dynamite-fuze nor a 30·86 grains detonator will ignite a safety-cartridge having a density of 1·6 to 1·7, the most suitable density being 0·8.

* *Trans. Fed. Inst.*, vol. xi., page 2.

The dispersive power, and therefore the danger, increases with the proportion of hydrocarbons, and with the strength of detonator used; on the other hand, ammonium oxalate and the salts of chlorine, bromine, and iodine diminish both the strength and danger of the explosive.

Among their drawbacks may be signalized the low specific gravity, necessitating bore-holes of larger size; and their hygroscopic character, which, however, may be guarded against by careful packing.

It is considered that Mr. Siersch's photographic method will afford valuable aid in determining the relative security of safety-explosives. As an example of the safety of progressit the following may be cited:—5·29 ounces of progressit exploded by a 30·86 grains detonator and lying in 6·6 pounds of coal-dust in an atmosphere containing 2½ per cent. of gas, caused no explosion of the latter, whereas 10·58 ounces of dynamite No. 1 produced a powerful explosion.

The same amounts of progressit and coal-dust with a 15·43 grains detonator failed to ignite the very dangerous amount of 10 per cent. of gas, although the test was repeated ten times. When a 30·86 grains detonator was used an explosion of gas resulted on two occasions, but not in the other two repetitions of the test. Even 14·11 ounces of progressit failed to ignite a 7 per cent. mixture of air and fire-damp when fired with a 30·86 grains detonator under similar conditions.

C. S.

PERCUSSION-DETONATORS.

Die Percussions-Zündung, System Tirmann. By JOSEPH POPPER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, *vol. xliii., page* 188.

One of the chief objects of the modern science of blasting is to discover explosives for mines which will not ignite fire-damp and coal-dust, and with them a safe and certain method of ignition is also required. Among the various systems, the author considers the Tirmann percussion-detonator one of the best. The fuze consists of a metal shell or cap containing a spiral spring, and a knob connected to the hooked ignition-wire. The spring is pressed together until, as the priming-wire gradually works out, the spring expands, drives the knob against a capsule, and fires the detonator. The invention was first tested in the deep shaft of a Moravian colliery, and showed the advantages of percussion-detonators for blasting, especially as regards certainty of ignition. Out of more than 500 detonators fired, there were at first 10 per cent. of miss-fires. To improve the apparatus, the priming wire was coppered over, and made much stronger, to prevent it from being cut against the sharp edges of the shot-hole. The small piston connected to the knob was lengthened, to make it deliver a more direct blow against the detonator, the knob steeled and sharpened, and the percussive force increased by strengthening the spring. Experiments on this improved fuze gave 3·3 per cent. of miss-fires, with capsules ½ inch, and a priming-wire 4 feet long. Most of the miss-fires were due to the composition of the capsules, which were not rich enough in explosive material. This was remedied, and the capsules were so arranged as not to touch the knob. The priming wire was made 6 feet long, that blasting might be carried out either in the thill or the roof of deep mines, and the results showed 1·25 per cent. of miss-fires in one case, and 0·6 per cent. in another. At first it was feared that the wire might break, but this has never happened, and after a miss-fire a new detonator, with a percussion-cartridge, has been refixed and fired without danger. It is necessary to connect the fuze to the cartridge, and embed it in clay; the latter is a point to which too little attention is usually paid.

The advantages of the Tirmann over the Bickford and Lauer fuses are that flying sparks are avoided, it is simpler, easier of manipulation, and more certain of effect. As the fuse is adjusted on the spot, while being rammed, premature explosions cannot occur.

For simplicity, economy, and precision of firing, it compares favourably with electricity. In the same mine, the percentage of miss-fires with electric ignition was 1·7 per cent. in 1893, and 2·2 per cent. in 1894. The favourable opinion entertained of the Tirmann fuse when it first appeared in 1889 has been justified with its present improvements, and it is already used not only in the Witkowitz mine, but in several others in the Ostrau-Karwin district. B. D.

DELAYED IGNITION OF GRISOUNITE CARTRIDGES.

Accidents survenus par suite d'Explosion tardive de Cartouches de Grisounite. By — Sarrau. *Report de la Commission du Grisou. Annales des Mines*, 1896, *vol. x., page* 126.

In February, 1896, the French Minister of Public Works requested the opinion of the Fire-damp Commission as to an accident which happened on December 20th, 1895, in the No. 1 Châtelus pit of the Beaubrun colliery, where a man was slightly injured by the delayed explosion of a mine-shot charged with grisounite. According to the official report, three shot-holes, put into the same working-face, had each been charged with 3½ ounces of *grisounite-couche*, which is composed of 95½ parts of ammonium nitrate and 4½ parts of tri-nitronaphthaline, to be detonated with 23·15 grains of fulminate. When fire was put to the fuses, the three men of the working-place, sheltered in the immediate neighbourhood, heard "three very distinct detonations, the two first almost simultaneous and the third, duller than the others, two or three seconds afterwards." They returned to the working-place; but at the moment they reached the face one of the shots, which was still smoking, wounded one of them in the face. It would, therefore, appear that the shot went off twice, the second explosion having been preceded by a partial one.

Inasmuch as three other similar cases had been reported, the circumstance was considered worthy of investigation; and, as the facts appear sufficiently well established for deducing from them a plausible explanation, it will be well to recall the phenomena connected with explosive decompositions. A great cause of variation in the decomposition of an explosive results from the pressure to which the products may be subjected during the reaction. Dynamite, and nitrated explosives generally, fuse slowly when freely exposed to the air, while giving out a large quantity of nitrogen dioxide; but the same substances fired in a strong and close chamber decompose rapidly without producing a trace of nitrogen dioxide. Moreover, the second and explosive mode often subvenes when some external circumstance increases the pressure by hindering the disengagement of gases; and this circumstance accounts for the accidents that have ensued from burning dynamite-cartridges in the open air, or endeavouring to obtain in tubes the fusing combustion of such substances as picrate of ammonium.

The reaction brought about by fulminate-of-mercury detonators does not differ from that caused by ignition in a close chamber under great pressure; but the decomposition is propagated with such rapidity that the whole mass tends to decompose in a volume differing but little from the original, thus producing enormous pressure even in the open air or with slight tamping. Defects in the detonator may cause a charge to fuse slowly, instead of exploding, the explosive decomposing in the manner characteristic of slight pressures, while producing

dioxide of nitrogen. In this respect nitrate of ammonium is specially insensible; and the explosive property of grisounite is only due to the small quantity of nitronaphthaline which it contains.

The Beaubrun accident appears difficult to account for, as the shot-hole was only charged with a single cartridge; but it must be supposed that some chance irregularity in the constitution of the charge sufficed to oppose, to the propagation of the explosion, an obstacle equivalent to that which might be caused by absence of contact between two cartridges.

Considering the special advantages, in fiery mines, in favour of the grisounites, and dynamites with nitrate of ammonium generally, it would appear that the accidents due to the slight sensitiveness of these explosives are too few and unimportant to cause their interdiction; and the only measures that seem advisable are to inform mine-owners of the accidents recorded, their circumstances and their probable explanation, and also to impress upon inspectors of mines the advisability of investigating and reporting upon similar accidents. At the same time mine-owners should warn their men using grisounites, or similar explosives, to allow a few minutes to elapse before returning to a shot when they notice any indication of incomplete explosion. J. W. P.

COMPOSITION OF FIRE-DAMP.

By M. Schloesing, Jun. *Comptes Rendus Hebomadaires des Seances de l'Académie des Sciences*, 1896, *vol. cxxii., pages* 398-400.

The author analysed a number of samples of fire-damp from typical French mines, with the view of ascertaining whether they contained other combustible gases than methane. In each sample the carbon dioxide and oxygen were first determined, and the remaining gas containing the nitrogen and the part entirely combustible was then submitted to a very careful eudiometric analysis. The results are given in the following table:—

	Source of the Samples.	Per 100 Vols. of the Samples.				Per 100 Vols. of Entirely Combustible Gas Burnt in the Eudiometer.	
		Carbon Dioxide.	Oxygen.	Nitrogen.	Combustible Gas.	Contraction.	Carbon Dioxide.
1.	Anzin, Hérin pit	0·4	0·5	2·2	96·9	200·4	100·8
2.	,, Renard pit, 476 metres level	0·0	0·1	3·5	96·4	201·4	101·9
3.	,, ,, 546 ,,	0·3	0·0	9·5	90·2	200·6	100·4
4.	Grand' Combe, Oules pit	1·1	9·5	16·6	81·8	200·9	100·2
5.	,, ,, Ravin pit	2·6	0·4	10·2	86·8	200·7	100·7
6.	,, ,, Forêt pit	4·1	0·0	7·1	88·8	201·0	101·3
7.	,, ,, Pontil pit	2·7	0·1	8·7	88·5	201·8	100·5
8.	,, ,, Tréts pit	3·3	0·8	14·8	81·1	201·5	100·5
9.	Steel-works of France	1·1	0·3	7·4	91·2	201·7	100·7
10.	Compagnac	0·7	0·0	6·8	92·5	200·3	100·5
11.	Saint-Etienne	0·4	0·1	4·9	94·6	202·0	100·7
12.	Plat-de-Gier	1·0	0·2	20·2	78·6	200·9	100·8
13.	Roche la Molière et Firminy ...	0·9	0·0	9·2	89·9	201·6	100·5
	Average	...	...	...	...	201·1	100·7
14.	Ronchamp, Chanois pit	0·7	0·0	6·6	92·7	202·3	102·7
15.	,, ,, ,, ...	1·2	0·1	8·1	90·6	203·2	102·6
16.	Blanzy...	3·7	0·9	39·8	55·6	203·7	104·3

Carbon dioxide was generally found in very small proportions, and might, moreover, arise partly from the water, by means of which the samples were collected. Oxygen formed a still smaller proportion, and might arise from the water or the admission of small quantities of air into the bottles in which the samples were carried. Nitrogen was present in very variable proportions, and often very high; it could not all proceed from the water nor from entries of air into the bottles; and the greatest part pre-existed in the fire-damp at the time of its collection. The proportion of nitrogen present was very carefully determined by another process, which confirmed the accuracy of the determination. The origin of the nitrogen is attributed to the penetration of atmospheric air, of which the oxygen had been absorbed by the coal. To confirm this conclusion tests were made for argon, and 1·1 of that gas was found per 100 of nitrogen, which is nearly the same as that found by the author in atmospheric nitrogen.

With reference to the contraction observed and the carbon dioxide produced, the theoretical figures for pure methane should be, contraction 200 and carbon dioxide 100, but the results obtained from a check experiment, in which chemically prepared methane was used, gave contraction 201·1 and carbon dioxide 100·4, that is to say, figures quite similar to those obtained with fire-damp. It is, therefore, concluded that none of the samples, save Nos. 14, 15, and 16, contained any appreciable quantity of combustible gas other than methane. The results relating to Nos. 14, 15, and 16, verified by numerous analyses, may be explained by the presence of a small quantity of ethane (from 2 to 4 per cent). Finally, it may generally be considered in practice that the combustible portion of fire-damp consists simply of methane, although it happens sometimes to contain a small but sensible proportion of some other hydrocarbon. W. N. A.

COMBUSTIBLE GAS IN A NON-FIERY MINE.

Note sur une Flambée de gaz survenue au Puits Marseille, Mines de Houille de Montrambert. By — LEPROUX. *Annales des Mines*, 1895, *vol. viii., page* 31.

On July 21st, 1894, a small blower of gas occurred in a cross-cut, at the level of 1,496 feet in the Marseille pit of the Montrambert colliery, Loire, France, slightly burning a man engaged in driving this cross-cut, to effect a junction with the sump of the Marseille shaft. Naked lights were exclusively used in the workings, the third *bed'aut* coal-seam having never been found to give out fire-damp in this district. By way of precaution, however, the overmen of each working-place carried safety-lamps, and were ordered, after each cessation from work, to try each working-place with the lamp before allowing the men to enter with naked lights.

The sump of the Marseille shaft had never been cleaned out; and, since 1889, all sorts of rubbish, wood, straw, coal, gob-material, lubricating-oil, dung, etc., had accumulated therein, rising to a height of 41 feet, covered by water. A hole bored in advance of the cross-cut and directed upwards, 15 feet long and 1¼ inches in diameter, terminated in the sump 24 feet above the bottom. The boring was finished during the night between July 17th and 18th, 1894; and the water at once began to flow through the hole, having traversed the whole mass of rubbish accumulated in the sump, and giving out a fetid odour. As the hole was liable to be stopped up by the rubbish, the men were told to keep it clear from time to time, in order to ensure a regular flow.

On July 20th, about 6 p.m., the contractor for driving the cross-cut tried the working-place for gas with his lamp, while two men waited for him at the junction with the cross-cut, at the level of 1,496 feet. As nothing unusual was noticed, the men

set to work at the cross-cut, being at 9 p.m. relieved by a third man, who with the contractor continued the work; and about 1·30 a.m. the two withdrew to rest at the junction. At 2·30 a.m., the man returned alone to the face, and, after having worked about two hours, went towards the bore-hole to see if the water was flowing freely. In order to see better, he was going to hitch his open lamp on to the horizontal timber of the last sett of timber; but at the same instant a flash burnt him slightly on the face, chest, and arms. He immediately went towards the contractor, who came to meet him, having heard an explosion, though his naked light had been extinguished by the rush of air. A man who had a safety-lamp at once tried the face in front of the air-pipes, in an unventilated *cul-de-sac* about 47 feet long, without finding any trace of inflammable gas; but, on presenting his lamp to the orifice of the bore-hole, so much gas issued as to extinguish his lamp.

It is difficult to admit that, if the measures in which the cross-cut was driven gave out gas, it should not have been perceived between July 18th and 21st; but the various considerations detailed by the author lead to the belief that the disengagement in question was one of marsh gas generated by the mud and rubbish accumulated at the bottom of the sump, and that it issued from the bore-hole as soon as the water had nearly all run off. J. W. P.

DISENGAGEMENTS OF INFLAMMABLE GAS FROM MINES OF PLASTIC CLAY.

(1.) *Note sur des Dégagements de Gaz inflammables survenus dans les Carrières d'Argile réfractaire de Bollène. By* — OPPERMANN. *Annales des Mines*, 1895, *vol. viii.*, *page* 5.

During the last few years, sudden outbursts of inflammable gas have occurred in the workings of the fireclay mines at Noyères and Jonquerolles, 2 miles to the south-west of Bollène, where the deposit forms a small basin about 5,000 feet long by 1,000 feet wide, bearing north-east and south-west. The fireclay beds, undulated and divided into three distinct basins, are much inclined on the north-east, as also are the white sand on which they rest. The maximum thickness of the bed is 65 feet, of which 40 feet are workable. In the centre of the basin, the winding-shafts encounter the clay at a mean depth of 100 feet; and their total depth may be 160 feet. The fireclay, of good quality, is grey in colour; and, at the bottom of the stratum, when in contact with the white sand, it is generally variegated and then pink-coloured, being sometimes replaced by a soft sandstone. The white sand contains much water, so that great care is taken not to work the fireclay beyond the variegated portion; but the workings are often invaded by water, which penetrates through the fissures, traversing the clay, in which case the shaft is abandoned until the spaces are partly filled by the clay It is also by virtue of this natural gobbing, due to the plasticity and progressive subsidence of the clayey mass, that the deposit may be worked over its whole thickness while keeping to the same level. When the shaft is put down to the lower portion of the workable deposit, a gallery is driven from the bottom to a length, generally from 30 to 160 feet, depending on the thrust against the timber supports. Working-places are driven right and left of the drift when this can be done without danger; and, when the thrust becomes too great, the men work back towards the shaft, taking out as much of the timber as possible. Fresh drifts are then driven in other directions; and in about a year the first drift is sufficiently filled up for a new one to be driven in its place, so that working can be carried on several times in succession at the same points.

It is only when nearing old workings, that have been abandoned owing to incursions of water, that disengagements of inflammable gas occur; and it is always noticed that the excavations where gas is found contain much prop-wood that could not be taken out on account of the suddenness of the inburst. Although the quarries were worked before 1840, the gas disengagements were not noticed before 1866, after which they have continued at variable intervals. This phenomenon only occurs in the working-places approaching old workings that have been incompletely filled by the clayey mass, denoting the near proximity of cavities in which the gas has accumulated under pressure, escaping violently through fissures and being accompanied by a characteristic whistling sound. The men light the blower with their lamps and allow it to burn out, one having burnt for 5 days; and the blue flame, edged with yellow, is identical with that given out by the combustion of hydrocarbons.

The fireclay contains no organic matter the decomposition of which can generate methane; nor does the gas come from the depths of the earth. It is possible that the white sand contains lignite-seams; but lignite cannot give out methane. The fact that the gas always proceeds from old workings containing prop-wood, being more abundant with poplar than with pine or oak props, leads to the supposition that the gas is generated by the decomposition of the timber, after the manner of the fermentation of which cellulose is susceptible.

J. W. P.

---

(2) *Note sur des Dégagements de Gaz inflammables survenus dans les Glaisières de Vanves et de Malakoff, Seine.* *By* — HUMBERT. *Annales des Mines*, 1895, *vol. viii., page* 19.

The clay-bed worked in the environs of Paris, overlain by the coarse limestone, is divided into two parts by a band of tolerably compact blackish sand, known by the name of *cendrier*. Between the lower limestone-beds and the clay is a water-level, a second being met with at the base of the blackish sand, in which a large quantity of iron pyrites is found, while the clay itself is ferruginous. The lower and less pure bed contains lenticular masses of lignite, often accompanied by pyrites.

The clay is generally worked by shafts and headings, a main gallery being driven from the bottom of the shaft into the mass of clay, from which workings are driven at right angles. For preventing the overlying clay from filling up the headings, careful timbering is necessary, notwithstanding which the workings cannot be pushed forward too far from the shaft without compromising the mine, as clay constantly tends to fill up the spaces. Ventilation is effected by a stove at the bottom of the shaft, with its chimney rising to the surface, exceptionally supplemented by a fan. When the headings cannot be driven farther from the shaft, they are abandoned, as much of the timber being taken out as possible; and, after a few years' working, they can be resumed in the same place without any traces of the former excavations being found.

On September 10th, 1894, in an underground clay-pit at Malakoff, near Paris, an accident, resembling a fire-damp explosion, was caused by the ignition of gas that had accumulated in the workings; and other similar disengagements have occurred, but always in the old quarries that have been worked at successive periods. It is not rare for the gas to escape with a whistling sound from natural fissures or more frequently from the advance-holes bored for detecting pockets of water in the old workings. In most cases the men set fire to the blower, while lying on the floor, when a flame of greater or less length is maintained for a few minutes. The gas is not, however, always inflammable, and, if not lighted at once, may spread itself over the working-places and be ignited by the candles, when an explosion will take place, serious in proportion to the length of time that the gas has

accumulated. On one occasion when a man, let down in a bucket by a windlass, was being drawn up after igniting the gas, he was blown completely out of the shaft, 80 feet deep, and fell, burnt and lifeless on the surface, while the men turning the windlass and two others were blown to considerable distances. In all cases, the gas under pressure escapes from pockets that can only be due to the spaces left by former workings, all the disengagements having taken place in old clay-pits. The inflammable gas, which is evidently mingled with air in the pockets and gives out a special odour, must be attributed to the decomposition of pitwood left in the abandoned workings. It is, however, by some persons attributed to the lignite intercalated in the clay; but the lignite is present in too small quantity to account for the considerable disengagements that have taken place, while it does not explain the characteristic odour of the gas nor its uniform absence in recently worked clay-pits. It appears, therefore, certain that the old timber decomposes in the clay pockets through the action of water and compressed air—very slowly it is true; but many of the clay-pits near Paris have been worked for a long period. J. W. P.

TESTING RETURN AIR-CURRENTS IN THE SAAR COAL-FIELD, GERMANY.*

Königliche Bergwerksdirektion Saarbrücken, July 11th, 1896.

Last year 950 analyses were made of the return air-currents of the twenty-four collieries comprised in the eleven mine-inspection districts of the Saar coal-field; and the following table records the results obtained at each colliery:—

Name of Colliery.	Yearly Output. Tons.	Volume of Fire-damp (CH_4). Per 24 Hours. Cubic Metres.	Per Year. Cubic Metres.	Per Ton of Coal Produced. Cubic Metres.
1. Altenwald	424,614	3,597	1,312,905	3·092
2. Burbachstollen	142,516	6,336	2,312,640	16·227
3. Camphausen	328,599	24,432	8,917,680	27·138
4. Dechen	384,710	4,617	1,685,205	4·380
5. Dudweiler	569,632	18,202	6,643,730	11·663
6. Friedrichsthal	190,313	2,083	760,295	3·995
7. Geislautern	58,973	2,196	801,540	13·592
8. Gerhard	216,935	21,413	7,815,745	36·028
9. Gottelborn	189,365	841	306,965	1·621
10. Heinitz	644,328	12,359	4,511,035	7·001
11. Itzenplitz	259,704	407	148,555	0·572
12. Jägersfreude	30,554	322	117,530	3·847
13. Kohlwald	338,269	7,508	2,740,420	8·101
14. König	415,324	17,156	6,261,940	15·077
15. Kreuzgräben	238,373	13,164	4,804,860	20·157
16. Lampennest	175,451	1,733	632,545	3·605
17. Maybach	405,695	13,500	4,927,500	12·146
18. Reden	433,204	34,621	12,636,665	29·170
19. Schwalbach	415,173	7,681	2 803,565	6·753
20. Serlo	120,371	22,065	8,053,725	66·908
21. Sulzbach...	211,258	3,612	1,318,380	6·241
22. Viktoria...	388,302	7,645	2.790,425	7·186
23. Von der Heydt... ...	248,156	3,467	1,265,455	5·099
24. Wellesweiler	28,371	3,293	1,201,945	42·365
Totals and averages...	6,858,190	232,250	84,771,250	12·361

J. W. P.

* *Trans. Fed. Inst.*, vol. x., page 564.

COQUILLON FIRE-DAMP INDICATOR.

Modifications apportées au Grisoumètre de M. Coquillon et permettant d'obtenir une Approximation de un dix-millième de Grisou dans une Atmosphère donnée. By — COQUILLON. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, *page* 32.

A bell-glass (the indicator proper) of about 12 cubic inches (200 cubic centimetres) capacity is closed below by an indiarubber plug having four holes, in two of which are inserted the brass poles carrying a platinum spiral, occupying a position inside and at the bottom of the bell-glass, their other ends being connected by copper wires with a Bunsen battery or hand-worked magneto-electric machine. Through the other two holes pass glass tubes, of which one rises to the top of the bell-glass, is bent at right angles underneath the plug and then separates into two vertical branches one of which, called the aspirator or expulsor, is connected with a smaller bell-glass for receiving the samples, while the other dips into a trough or basin containing the sample bell-glass. The tube in the fourth hole, rising less than 1 inch above the plug, continues downwards for a length of about 4 inches (10 centimetres) being graduated and having a bulb at its lower end, after which it is connected with a closed glass flask that may be raised or lowered.

For determining small quantities of fire-damp, this latter tube has a diameter of only 1 or 2 millimetres, so that 0·061 cubic inch (1 cubic centimetre) may be divided into 25 or 50 equal parts; but for larger proportions of methane, when so near an approximation is not required, it may be made of a larger diameter. A hollow glass cylinder surrounds the central bell-glass for giving water circulation, and thus maintaining the gas at a regular temperature, the whole being kept in place by a suitable stand.

When making the apparatus ready for use, the large bell-glass and the smaller bell-glass for receiving the sample are filled with water of as nearly as possible the same temperature as the circulation water; and the adjustable flask, filled with the same water, is raised so that the water shall flow into the graduated tube and through it into the large bell-glass, the air escaping by the pipe that dips into the trough.

When all the air is driven off and the whole apparatus is filled with water, the cocks are closed, when the gas to be analysed is introduced under the small bell-glass, and then made to pass into the large bell-glass by opening the proper cocks and lowering the adjustable flask, being stopped a little below the platinum spiral when, by a suitable manipulation of the cocks and continuing to lower the flask, the water will drive before it, through the other tube, any gas which may have remained therein, and which would otherwise have escaped being burnt. When the water reaches the top of this tube, the cocks are closed; and the flask is maintained in its then position, the water stopping at a certain level. If the level of the water in the flask be higher than that in the graduated tube, the experiment is conducted under pressure; and this is what the inventor prefers, in order that the gas on expanding shall not leave the graduated tube. When the level becomes constant, the platinum spiral is raised to a white heat by being connected with the source of electricity.

The experiment may last 20 seconds, which is generally sufficient; but it is advisable to make the platinum spiral incandescent twice running, so as to ensure everything being burnt. The gas requires a certain space of time to return to the starting point; and after from 10 to 12 minutes, with air containing 0·0001 part of methane, it will have exceeded its original level by several millimetres.

For measuring so slight a proportion of this gas, 10 parts of formene are mixed with 990 parts of air; and then 10 parts of this mixture are introduced into a flask containing 990 parts of air; thus giving the above-named proportions to the mixture introduced under the sample bell-glass. J. W. P.

HARDY FIRE-DAMP INDICATOR.*

Le Forménophone de M. E. Hardy: (1) *Rapport présenté à la Commission du Grisou par* — TERMIER; (2) *Avis de la Commission;* (3) *Note additionelle. Annales des Mines*, 1896, *vol. ix., page* 577.

The Hardy fire-damp indicator is an apparatus revealing immediately, and without the necessity of chemical analysis, the presence of fire-damp in a given atmosphere, and even for indicating its proportion with a very near approximation. It is a densimeter, founded on the well-known facts that the sharpness of sound given out by a sonorous tube is a function of the density of the gas which causes it to vibrate, and that two sounds of very nearly equal sharpness produce a discord.

The apparatus consists essentially of two identical sonorous tubes, supplied, one with pure air, and the other with air in which the presence of fire-damp is suspected. These two gaseous currents being brought to exactly the same temperature, and to complete saturation, and both being freed from any carbonic acid which they may have contained, the two tubes will sound in unison if the second current contain no fire-damp, but they will give out two slightly different sounds if the second current be at all impregnated with gas.

The conclusions of the commission appointed by the Paris Academy of Science are practically as follow:—The sensitiveness of the method is sufficient; but, in all probability, it may still be slightly increased. An improvement specially recommended by the Commission is that the apparatus be arranged so that each discord shall set up a mechanical effort capable of working a recorder; and the safety of the mine would be greatly increased if the engineer and the workman in charge of the ventilating-fan saw traced before their eyes a diagram showing continually the proportion of fire-damp in the return air-ways.

In accordance with this opinion Mr. Hardy, abandoning for a time the idea of making his apparatus portable, added a recorder, while modifying some details for increasing the sensitiveness; and this improved apparatus was submitted to the French Fire-damp Commission.

As a result of Mr. Termier's tests, the Commission concluded that the fire-damp indicator is not appreciably influenced, either by difference of temperature in the two gaseous currents, by their different carbonic acid contents, or by a difference in their hygrometric condition. Inasmuch as this question was set at rest, the tests made for the most part with low methane contents, were chiefly directed to determining the sensitiveness of the apparatus.

It was found that the sensitiveness is comprised between 0·001 and 0·002 parts when the tubes have previously been tuned in unison; and taking the thousandth parts as abscissæ, with the discords as ordinates gives a curve which, for contents higher than 0·008 part, approaches very nearly to a straight line, though being very irregular for lower contents.

It is therefore concluded that the Hardy fire-damp indicator will detect, correctly to about 0·001 part, the fire-damp content in a mine atmosphere. But if there be reason to bring this apparatus to the notice of mining engineers, it is not advisable, for the present, at any rate, and before practical tests have been made in the mine, to recommend it for general use.

* *Trans. Fed. Inst.*, vol. vi., page 80.

This opinion, which concludes Mr. Termier's report, was endorsed by the French Fire-damp Commission, upon which the inventor proposed certain modifications for meeting their objections; but the Commission considered that such modifications would render even more necessary the submitting of the apparatus to practical tests before it can be recommended for use underground. J. W. P.

FIRE AT THE KLEOPHAS COLLIERY, UPPER SILESIA.

Das Unglück auf Kleophas-Grube in Ober-Schlesien. Anon. *Glückauf*, 1896, *vol. xxxii., pages* 193-197.

The Kleophas disaster took place on March 3rd, 1896, and resulted in the loss of 104 lives. Moreover, all the pit ponies, thirty in number, were suffocated. The colliery is situated not far from Kattowitz and Zalenze, and is regarded as one of the best-planned and best-equipped of the more recent deep workings in Upper Silesia. It was started in 1886, and in 1895 the annual production averaged 400,000 tons for 1,500 workpeople. Under normal conditions, the ventilation of the pit is exceedingly good, but it is contrived on the old furnace system.

The workings are divided into two districts, in one of which the Kleophas coal-seam proper is worked at the 410 and 540 feet levels, while in the other the Gerhard coal-seam is worked at the 1,460 feet level. There are two winding-shafts, one only of which goes down to the deep level; two ventilating-shafts, one on either side of the shorter winding-shaft, are provided for No. 1 district; in No. 2 district the deep winding-shaft serves as a downcast, while a so-called blind upcast shaft conveys the return air to the floor of the levels in No. 1 district, into which it debouches.

At 9 p.m., March 3rd, 1896, fire broke out in the blind upcast pit; five men were at work here on repairs, and seeing all alight below them, fled to the winding-shaft, were drawn up to bank, and gave the alarm. Meanwhile, the flame and smoke were rolling in vast clouds from the burning shaft to the shorter winding-shaft some 200 feet distant, and were driving before them inflammable [and poisonous] gases, mixed with the fresh air all over the workings of No. 1 district. At 10·30 p.m., the woodwork in the winding-shaft having in turn caught fire, this shaft also began to act as an upcast, causing a reversal of the ventilation.

Owing to various circumstances, it was not found possible to complete the work of damming off the area of conflagration until the following day at 10 a.m. Meanwhile, the dense column of smoke and sparks which continued to belch forth from the shorter winding-shaft had made any approach to that shaft from above bank impossible. By means of the longer winding-shaft, the seventy men at work in the deep level (No. 2 district) had been safely brought to the surface. Then one of the overmen succeeded in cooling down one of the ventilating-shafts, and extinguishing the furnace by means of a spring of water, which he tapped some 100 feet down the shaft, and proceeding from this shaft all the eastern portion of No. 1 district was ventilated and traversed by rescue parties, seventeen persons being saved from that portion. Rescue work in the western portion was much less successful and infinitely more difficult; fresh relays of men had continually to be sent down to carry out and remove the rescuers overcome by the gases, and at 9 p.m., on March 4th, all hope of saving further lives was abandoned. The next day, the work of searching for the bodies of the dead was resumed and completed without much further difficulty.

Though the writer does not state it in so many words, one infers that all those who were killed in this disaster succumbed to gas poisoning.

In comparison with the great loss of life, the damage sustained by the workings was but slight and, on the whole, easily reparable. O. S. E.

INTERCEPTION OF DUST AND METALLIC FUMES.

Note sur la Condensation des Poussières et des Fumées métalliques. By U. Le Verrier. *Bulletin de la Société de l'Industrie Minérale*, 1894, *vol. viii., page* 929.

The condensation of smoke and dust, which has given rise to much investigation in connexion with lead-works, possesses great interest as regards other industries; for instance, blast-furnace gases should be completely freed from dust for ensuring the proper working of the hot-air stoves. The means successively employed for this purpose have been: (1) completely cooling the gases, which is necessary for condensing volatile metals; (2) intensifying the deposit of dust mechanically, while diminishing the speed or causing disturbances in the air-current; and (3) washing the gases so as to damp the dust.

At the Ems lead-works, suspended sheet-iron pipes are used, with a series of hoppers, forming joint, for collecting the dust, which is made to pass through chambers with double sides cooled by water-circulation. The Tarnowitz serpentine ovens effect the cooling down still more effectually, because the cold bodies constitute an obstacle for splitting up the gaseous current. In some ironworks in the east of France the blast-furnace gases traverse a bed of iron wires (*paille de fer*), contained in a plate-iron case with perforated bottom; and in the Luxemburg ironworks they pass through large plate-iron drums, where they lose their speed, a better effect of the hot-air stoves having been obtained by increasing the number of these drums. J. W. P.

CONTINUOUS AND AUTOMATIC APPARATUS FOR TAKING SAMPLES OF AIR OR GAS.

Note sur un Auto-capteur ou Appareil servant à effectuer, automatiquement et de façon continue, des prises d'Air grisouteux ou de Gaz quelconques. By — Petit. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1895, *page* 293, *with diagrams.*

The object of this apparatus is to reconstitute to a certain extent, at the end of each day, by a curve of the fire-damp content in a mine atmosphere, the history of any given working-place capable of discharging considerable quantities of fire-damp into the air-current, in order to arrive at a knowledge of the laws that govern the issue of the gases enclosed in the coal. As its name implies, the apparatus is not a fire-damp indicator, but a sample-taker, for collecting automatically, and almost continuously, samples of the mine atmosphere impregnated with fire-damp for analysis in the laboratory by the limits of inflammability method.

The principle of the apparatus, by which a gas sample of predetermined volume is taken during a period of time that may be regulated at will, depends upon the following arrangement:—Suppose a closed vessel filled with any liquid, water for instance, supported at some distance above an empty vessel or pan, open to the air, and the two vessels connected by pipes, provided with stop-cocks, one pipe reaching from a given level in the closed vessel to near the bottom of the open pan, and the other extending from a given level in the open pan to the top of the closed vessel. The two levels are so regulated that, when the liquid from the closed vessel passes through one pipe into the open pan so as to lay bare the top of that pipe, it just closes the lower orifice of the other pipe, the liquid that was contained in the closed vessel being now replaced by an equal volume of the surrounding air.

In this apparatus, the closed vessel is made of inverted conical form, with the object of permitting samples of the same volume to be taken in equal spaces

of time; and six or more cylindrical receptacles of slight height are arranged spirally around it, being connected by pipes with stop-cocks, the whole, with the open vessel (called an aspirator) in the middle, being united by a light wire framework that can be carried into the mine. The total weight is 27 lbs., the diameter 17 inches, and the height 19 inches.

An air-sampler thus arranged was erected in a working-place in a seam worked by the trial-shaft of the Saint-Etienne colliery. The apparatus was purposely placed as near as possible to the face, in a very dusty place traversed by an air-current moving at the rate of 16 feet per second, with the object of making a crucial test. The series of investigations and the daily curve showing the variation in fire-damp content promise to be very interesting, and to contribute much information as to the disengagement of fire-damp. J. W. P.

COMPOSITION OF MINE-ATMOSPHERES IN THE DONETZ COAL-FIELD, RUSSIA.

La Composition de l'Air des Mines dans le Bassin du Donetz. By N. Kotsovsky. *Revue Universelle des Mines, etc., 1895, vol. xxxi., page 50.*

In 1889, the author obtained a grant from the Russian mine department in aid of studying the fire-damp question in the Donetz coal-field; but, scarcely were the analyses begun at the mining institute, when an explosion of unprecedented extent occurred on January 4th (old style), 1891, at the Rikovsky colliery, in the Donetz coal-field, causing the loss of fifty-eight lives and great destruction to the underground workings. From the facts observed after the accident, the author is convinced that it was caused by the insufficient ventilation, the exclusive use of naked lights and the intentional ignition of the blowers of gas.

The samples of mine-atmosphere examined were collected from five collieries, in three of which fire-damp was present in large proportions; and the following table gives the mean of the results obtained:—

	Per Cent. by Volume.			
	Carbon Dioxide.	Fire-damp.	Oxygen.	Nitrogen.
Rikovsky colliery, No. 10 pit ...	0·29	51·96	8·99	39·66
Fire-damp from the same mine, collected after the explosion ...	0·57	61·08	3·81	34·54
Ilowaysky colliery, Capital pit ...	1·04	64·91	3·6	30·45

These results are comparable with those obtained for the mine-atmospheres of Western Europe; and, if the quantities of fire-damp are rather less than those of other districts, the difference is explained by the intrusion of a certain quantity of atmospheric air into the tubes when being filled. These results warrant the belief that the fire-damp in the Donetz collieries filters, through fissures in the coal, into the workings in an almost pure state, after the manner of blowers. This kind of emanation is most dangerous, because working may at any time lay bare the fissures through which the gas escapes, sometimes in large quantities and under considerable pressure.

Most analyses of the air circulating through the mines have been made, according to the reports of fire-damp commissions, on air collected in the upcast shaft and return air-ways, the results indicating the quality of the air in the mine generally and the state of the ventilation, while the air of the working-places has been but rarely analysed. To ascertain the quality of the air in the Donetz collieries, the author collected, in various working-places, the air breathed by the miners, and gives tables showing the results of analyses.

The author's conclusions are as follows: In the collieries of the Kalmious valley, not only is the existence of fire-damp proved, but this gas is present in so large a proportion as to demand the most stringent measures of safety, especially in those mines where it filters into the air of the workings through fissures and in the form of blowers. The air of the collieries examined from this point of view is rendered unhealthy by adventitious matters, proving a defective ventilation, which is now, however, being remedied in some cases by the erection of powerful ventilators.

It is absolutely necessary to test the air in all the collieries of the Donetz field, and also to divide them into classes according to their degree of danger. Such an examination would alone prevent the necessity of imposing on all the collieries of the country such stringent regulations as might be too severe and difficult to carry out in many of them. J. W. P.

ORIGIN OF SUBTERRANEAN CAVITIES AND THEIR CONNEXION WITH MINERAL VEINS.

Application géologiques de la Spéléologie. By E. A. MARTEL. *Annales des Mines*, 1896, *vol. x., page* 5.

A knowledge and study of the earth's natural cavities is of the highest interest to geologists, engineers, and hydrologists; the intimate relation of natural wells, caverns with springs, subterranean waters, dislocations of the earth's crust, metalliferous veins, etc., constituting the elements of this interest.

During the last eight years, the author has devoted all his leisure to penetrating the recesses of many unknown cavities, prosecuting his researches with several collaborators, not only in the various cavern-regions of France, but also in Belgium, Austria, Greece, England, and Ireland. These subterranean researches have, in ten years, not upset hitherto received ideas, but practically confirmed the correctness of several geological theories, destroyed some erroneous hypotheses, terminated many controversies, and strengthened opinions as to the internal phenomena of the external portion of the earth's crust, while revealing the existence of many caverns which are useful to know for many reasons.

There are two principal causes for the formation of natural cavities: the pre-existence of fissures in the rocks, and the work done by the waters of infiltration. As regards the origin of caverns especially, it is convenient to distinguish two varieties of fissures in the rocks, the lithoclases and the joints, although this latter term has given rise to the most contradictory definitions and a troublesome confusion between stratification-planes and older fissures, so much so that the author has determined to apply the term "joints" to stratification-planes, while adopting for all other fractures the names and sub-divisions of the lithoclases, formulated by the late regretted Prof. Daubrée.

All that the author has observed in more than 300 natural caverns and springs confirms the general notion that the earth's fissures, due both to the large dynamical dislocations of the earth's crust, and to the more restricted effects of fracture by desiccation, contraction or compression in the rocks themselves, have been the general directing-lines of the cavities, which are commonly called the lines of least resistance. Prof. Daubrée's simple law as to the genesis of grottoes and natural wells, that the chief part is played by underground fractures, is subject to certain exceptions deriving their origin from petrographical dissemblances in the various formations.

The author examines, in turn, how the water has made use of the canalization, to a greater or less extent prepared in advance, how it has enlarged and modified

the more or less ample veins for establishing its underground circulation, and how it has here and there transformed this canalisation into caverns which are often of great extent. As to the origin of caverns no theory can be universal, almost all being partially correct, though each one that has been proposed has generally been too exclusive; and the truth may sometimes be found in their combination, and sometimes again in the application of one or other, according to each special case.

It will be readily understood that relations can exist between natural wells, caverns, and springs on the one hand, and metalliferous veins on the other, since the natural fractures have directed both the excavating work of subterranean water and the precipitation of the metallic emanations. In the various phenomena of alteration and again putting in motion of the ores, produced by the surface water on the upper portion of the veins, and especially when the latter cut the limestone; the intervention of veritable grottoes contiguous to these veins has often been noticed, minerals taken from neighbouring deposits having sometimes been redeposited by a secondary action. These cavities were, in fact, hollowed out long after the deposit of the primitive metalliferous bed, when the surface of the soil had already attained its present level; and it will be understood that the waters, acidified by their contact with the various metallic sulphides, in presence of the atmospheric oxygen, must have exerted an intense corrosive action on the limestones. J. W. P.

GOLD EXTRACTION: THE CASSEL-HINMAN BROMINE PROCESS.

By P. C. McIlhiney. *Journal of the American Chemical Society*, 1896, *vol. xviii., pages* 451-456.

The Cassel-Hinman process, which is intended for the treatment of low-grade ores unsuitable for amalgamation, such as the telluride ores of Colorado, is practically the same, as regards the *modus operandi*, as that of the chlorination process.

The ore, after being crushed, dried, sifted, and roasted, if necessary, is treated either by percolation in vats, or, preferably, by being agitated in revolving-barrels with an aqueous solution of bromine of an apparent strength of about 1½ per cent. The liquid is then drawn off, and the ore dried, etc. The recovery of the bromine from the liquid, which is the chief and essential feature of the process, is effected by adding thereto either (1) bleaching powder, or (2) potassium permanganate, and (3) sulphuric acid. The liquid is afterwards heated by direct steam in a covered stone tank, the bromide vapour being condensed in an earthenware worm, which when brought into contact with weak wash liquor from previous operations regenerates bromine solution for future use. It is stated that from a bath containing 15 lbs. of bromine per 100 gallons, the whole of the halogen is expelled when 5 per cent. of the liquid has been distilled.

It is claimed that, as a solvent for gold, bromine is more rapid and thorough in its action than chlorine, and on account of its greater solubility in water it may be used in solutions containing as much as 3 per cent. Another advantage claimed is that, unlike chlorine, bromine attacks but to a small extent the useless constituents of the ore, the proportion converted into bromide being only a little in excess of that corresponding to the gold dissolved.

Owing to this fact, the preliminary roasting of the ore to destroy sulphides, etc., which is so essential in the chlorination-process, need not be carried on to so great an extent, resulting in a great saving (as certain ores, such as tellurides of gold, lose a large proportion of the precious metal, either mechanically or by volatilization, during the final stages of roasting). M. W. B.

GOLD EXTRACTION BY POTASSIUM CYANIDE.

By J. LOEWY. *Chemische Zeitung*, 1896, *vol. xlix., pages* 479-480.

The author gives the results of experiments conducted with a refractory gold-ore from the Lydenburg district, Transvaal, treated with different cyanide solutions. The ore contained about 9 dwts. of gold per ton and 2·59 per cent. of copper, the extractions being as under :—

Strength of Cyanide Solution. Per Cent.		Gold Extracted. Per Cent.		Copper Extracted. Per Cent.
0·5	...	15·2	...	4·5
1·0	...	13·7	...	8·4
2·0	...	48·0	...	19·6
5·0	...	53·0	...	over 25·0
10·0	...	76·5		

The author considers the MacArthur-Forrest recommendation to use weak cyanide solutions of from 0·2 to 1 per cent. for refractory ores as unsound, contending that such solutions give an inferior extraction. On the other hand, the stronger the solution the greater will be the amount of base metals and of gold dissolved. He also considers that the cyanide process is unsuitable for most refractory ores, the strength of cyanide required being too high and the time for extraction excessive. M. W. B.

GOLD MINES OF THE DUERNO, SPAIN.

Minas de Oro del Duerno, en la Provincia de Leon. By R. ORIOL. *Revista Minera*, 1896, *vol. xlvii., pages* 197-199.

The auriferous formation in the province of Leon extends over the western boundary into Orense, and is divided into four groups, viz. : The hydrographical basins of the rivers Duerno, Eria, Cabrera, and Burbia, the two first-named discharging into the river Douro, and the second pair into the river Sil.

The basin of the Duerno lies south of Astorge and on the northern slope of Mount Teleno, over 3,000 feet above the sea-level. The auriferous formation occurs on both sides of the river, the principal portion being on the right bank and traversed by the brooks Espino and Llamas. It occupies an area of some 9 miles in length by about ¼ mile in width, and extends to depths ranging from 30 to 200 feet between Molinaferrara and Priaranza. There are traces of the mining operations carried on by the Romans at los Castellones, Fucochicos, etc., and some more modern water-channels in good repair, for conveying the water of the Espino and Llama to the workings above los Castellones.

The basin of the Eria lies on the southern slope of Mount Teleno, and is traversed by several streams. The gold-bearing formation extends around the outskirts of the hamlets of Truchas, Manzaneda, etc., but is of less importance than that of the Duerno valley.

The Cabrera basin lies west of Mount Teleno, and the gold occurs between Yeres and Caruce, near Mount Médulas, where there are several distinct water-channels, some 18 miles in length. Other remains show that the formation must have been worked on a large scale. In places, it exhibits a thickness of 500 to 600 feet.

The basin of the Burbia extends northward from Villafranca del Vierzo through a mountainous region on the borders of Leon, Lugo, and Asturias. The formation is met with on both banks of the river, and there are numerous remains of Roman workings. Hills of auriferous conglomerate extend to the river Candin, near Prado. The district is over 3,000 feet above sea-level, and the workings have, in some places, exposed faces of auriferous earth as high as 550 feet.

The Duerno basin presents the greatest advantages for working the deposits, in that the formation is more superficial and lies close to the water, thereby entailing little expense for the construction of sluices, and avoiding the necessity for making such large expropriations as would be the case in the other districts. These reasons induced the author to advise the El Oro Español Company to acquire the Duerno property.

The formation consists of a diluvial mass of recent geological origin, reposing on a bed-rock of Lower Silurian formation. It has been elevated along with the Cantabrian Mountains, and subsequently suffered denudation with the formation of river-valleys. Probably, also, some parts of the formation have been covered by the deposits of alluvium in the lower districts of Leon. The diluvium possesses marked characteristics which distinguish it from modern alluvia, and the cementing material has acquired sufficient coherence to preserve the face of the Roman workings almost perpendicular to heights of 550 feet, giving them the appearance of having been only recently abandoned. The circumstances of deposition appear to have varied; where the formation is thin the stones in the lower layer are large and decrease progressively in size in the superior portion, but where the thickness is greater the deposits of stones are separated by beds of pure clay, the arrangement indicating alternations of agitation and repose in the course of sedimentation. The angular shape of the stones shows they cannot have been transported from any great distance, and their nature points to an origin in the Cambrian, Silurian, and Devonian rocks of the Cantabrian range. White vein-quartz is rare, and the author inclines to believe that the presence of the gold in this formation is due, in great part, to chemical action in the water depositing the conglomerates, being led to this opinion by the absence of auriferous veins, the sterility of the stones, the intimate dissemination of the gold throughout the ferruginous clay cementing the conglomerate, and the generally expressed opinion that the richness in gold varies directly with the proportion of ferric oxide in the mass. Concretionary lumps of hæmatite are found, indicating the abundance of iron in the depositing water.

The Romans worked these mines by sluicing and arresting the auriferous earth in the tail-races by means of heather and branches of trees, which they subsequently burnt. The best course to pursue at the present time will be to ascertain by experimental working on a small scale the average proportion of gold in the conglomerate, and the most suitable means of recovering the metal from the concentrated cement—whether by amalgamation, the cyanide process, etc. In this way, only a comparatively small capital need be risked at the outset, and the experience gained will enable the proper methods to be adopted at once if the preliminary venture proves satisfactory. C. S.

THE PRESENT METHOD OF DECLARING THE MONTHLY OUTPUT OF GOLD OF THE WITWATERSRAND DISTRICT, WITH A SUGGESTION FOR ITS ALTERATION.

By A. Von Gernet. *The Standard and Diggers' News, Johannesburg, July 20th, 1896.*

The output of gold for the above district is now declared by the Chamber of Mines and the Association of Mines, who continue to follow out the practice of declaring the output in bullion ounces.

The author draws attention to the fact that an ounce of gold bullion as obtained in this district varies considerably in value, by reason of the different chemical processes now in use and by the variation of silver and other alloy in mill gold, according to the kind of ore worked.

When the present system of declaring the monthly output of gold was first introduced, the whole of the production of the district was obtained by mill yield from free milling ore, and the output might then fairly have been considered to be of an average value per bullion ounce; but this no longer exists, and to-day the monthly declaration is made in ounces, which vary from say 600 fine—in the case of cyanide gold—to 995 fine in the case of chlorination gold, or from say £2 10s. 11d. per ounce to £4 4s. 6d. per ounce, home values—which shows a difference of £1 13s. 7d. per ounce.

The author submits that the output of this district should be either declared in £ sterling, with no declaration of output in ounces, or else the declaration should be made in fine ounces.

Reference to the Chamber of Mines declarations for the past five years shows that the annual declarations are as follow :—

	Ounces.	Value. £	Value per Ounce. £ s. d.	Average fineness based upon a fine ounce being equal to £4 3s 6d.
1890	494,817	1,735,491	3 10 1·7	840
1891	729,238	2,556,328	3 10 1·3	839½
1892	1,210,868	4,297,640	3 10 11·8	850
1893	1,478,477	5,187,206	3 10 2	840
1894	2,024,168	6,903,100	3 8 9·6	824
1895	2,277,640	7,840,779	3 8 10·2	824½

The difference in the value of the bullion ounce, comparing 1892 with 1895, shows that it was worth 2s. 1d. less in 1895 than it was in 1892.

This difference upon the output of 1895 would amount to £237,000—that is to say, had the fineness of the bullion produced in 1895 been equal to that produced in 1892 the value of the 1895 output would have been increased by £237,000. Other large gold-producing countries declare their gold production in fine gold, and the author contends that this important gold-producing country should also declare its output in the same way. J. W.

GOLD METALLURGY ON THE WITWATERSRAND, S.A.R.

By W. R. Feldtmann. *The Standard and Diggers' News, Johannesbury, July 20th*, 1896.

Cyanide Process. The writer was surprised that so little had as yet been done toward lessening the irksomeness of a clean-up in works where zinc precipitation was used. He thought that it was largely due to the dirty and disagreeable work of cleaning up zinc that the electric precipitation on these fields had obtained such popularity as it possessed. He thought it would not be impossible to evolve a workable system of regulating the output from zinc boxes to bring it into some kind of proportion to the gold extracted from the ore, and of making the operation of cleaning up generally easier and less subject to loss. The desideratum was a combined chemical and mechanical process for removing all, or nearly all, of the gold from the zinc every month and a proper series of appliances for purification, by means of acid, of the gold before smelting. He felt confident that, if the same amount of ingenuity were expended on the working and cleaning up of zinc-boxes as had been devoted to electro-precipitation by the staff of the Rand Central Reduction Company, there would not be much more heard of the electric precipitation with its enormous initial outlay and costly working expenses.

Transvaal Gold Output Returns. The writer thought it seemed a curious anomaly that a certain number of bars of bullion, varying enormously in assay

value, should, in the Chamber of Mines returns, be lumped together with painstaking accuracy as to weight, as so many ounces of gold, no effort being made to reduce all the companies' outputs to the same standard of fineness. The exceedingly complete and instructive returns of the Chamber of Mines lost a great deal in accuracy owing to this one defect.

Dry Crushing and Direct Cyaniding. Within the next few months, it was anticipated that this much-vexed problem would be put to a thoroughly practical test in the Transvaal. The Afrikander Company, in Klerksdorp, are erecting a plant calculated to crush and treat 10,000 tons per month. From extensive experiments which have been carried out, the author had every confidence that the results of the cyaniding will be satisfactory, and will promote the question of dry-crushing from the region of debate into that of practical and useful technology.

J. W.

AURIFEROUS GRAVELS OF THE UPPER COLUMBIA RIVER, BRITISH COLUMBIA.

By FRANK L. NASON. *Engineering and Mining Journal (New York), 1896, vol. lxi., pages 279-280.*

The region of the Upper Columbia river, in British Columbia, known as the Big Bend, comprises the territory lying north of the Canadian Pacific Railway, between the stations of Golden and Revelstoke, thus including the northern end of the Selkirk Mountains, the western slope of the Rocky Mountains, and the eastern slope of the Gold Range. The dividing-line between the mining districts of East and West Kootenay also nearly equally divides the Big Bend, so that one half lies in East, the other in West Kootenay.

Little as is known of this region, extending over 100 miles north from the Canadian Pacific Railway, and for 75 miles along the road, this little knowledge is confined almost exclusively to the Big Bend of West Kootenay.

A good deal of attention is now being attracted towards the placer gold in Big Bend; but Trail Creek, the Slocan, and other famous places around the Arrow Lakes, the Cariboo, and Yukon fields, overshadow all else in the province. The longest of the tributary streams flowing into the Columbia river are rarely more than 15 miles in length, while many flow directly down the steep faces of the mountain, being fed directly by melting glaciers. These latter streams, flowing through cañon-like gorges, have no terraces. The *débris* brought down by them form either large deltas in the river, or the material is wholly swept away by the river Columbia. These streams form natural sluices, and have been the favourite hunting ground for "snipers" or "pocket-hunters." From Pothole Creek, a stream less than 1 mile in length, £8,000 worth of gold is said to have been found in one season.

Along the larger streams, such as Carnes Creek, Dordine Creek Gold Stream, Smith Creek, Gordon Creek, etc., the terrace-formations are very extensive, and all are, without exception, auriferous. On French, McCullough, Camp and Smith Creeks, and Gold Stream as well, enough work has been done to establish the fact that in many places the gravels are rich enough for hydraulic extraction.

The gold which occurs in the gravel follows the general rule, *i.e.*, if the boulders are coarse, well-worn, the gold will be found approximately under the same conditions. Large nuggets are not often found; those weighing £2 to £3 are very rare. The bulk of this gold will weigh from 1½d. up to 5d. or even 1s. About

3 per cent. will weigh from 2s. to 8s. Rusty gold is the exception rather than the rule. Platinum has never been observed by the writer, though native copper is occasionally met with.

From personal knowledge, the writer has satisfied himself that many river-banks have favourable conditions for hydraulic working on a large scale. Although somewhat difficult of access, and labouring under the disadvantages of short seasons, these difficulties are no greater than have been met and overcome in the United States, and with poorer gravels. J. W.

CAMP FLOYD MINING DISTRICT, UTAH, U.S.A.

By JAMES W. NEILL. *Engineering and Mining Journal, New York*, 1896, *vol. lxi., page* 85.

What the Cripple Creek district is to Colorado, the Camp Floyd district promises to be for Utah; indeed, it may safely be said already to be this, for "Mercur" is the most common topic with mining men nowadays. The camp is renamed after the principal mine, the Mercur, having been formerly known as Lewiston. Under that name, it flourished as a silver-mining camp from 1869-71, when Dry Cañon, Ophir Cañon, Lion Hill, and other camps on the western slope of the Oquirrh range were all producing silver ores of high grade and in large quantities.

The elevation of Lewiston, now Mercur, is 6,700 feet, and the town is similar in all it features to the mushroom mining towns of Colorado, with hotels, saloons, and stores.

The ores of the Mercur camp are of two kinds, the oxidized and the base, or arsenical, and each is peculiar in its own composition. The oxidized ore, which is that now being mined and treated by the Mercur Company and the other producing mines, is of a yellowish colour when seen in mass; its composition is mainly siliceous or quartzy matter, with much limestone mixed through it, all stained by a clayey or talcose substance, which gives the mass its colour, while each distinct species of rock retains its usual characteristics.

The base, or arsenical, ore, after roasting, shows itself to be of so porous a nature that it will yield as high a percentage of its values to the cyanide solution as does the regular oxidized ore; therefore it is only a question of roasting and getting rid of the arsenic fumes by some method of condensation. This latter point is vital to success, as the ore often runs up to 10 per cent. arsenic, and should there be a permanent plant to handle 100 tons per day, the fumes from 8 or 10 tons of arsenic in the surrounding atmosphere would no doubt be a serious matter to life.

The actual daily production in gold at the present time is as follows:—

	Tons.	Value per Ton. £ s.	Loss. s.	Net Value. £
Mercur	200	... 2 8	... 8	... 400
Marion	50	... 1 4	... 4	... 50
Geyser	50	... 1 4	... 4	... 50
Sunshine	50	... 1 4	... 4	... 50
Total daily output of producing mines				£550

Equivalent to an annual output of £200,000. The cost of mining, hauling, milling, and marketing product per ton of ore is currently quoted for the large producers at about 13s. per ton.

To the uninitiated, an examination of the tailings dumps from one of the Mercur cyanide mills would be a surprise, for some of these mills do not crush finer than ½ inch, which means that the tailings look more like road material than anything else.

J. W.

GOLD MINING IN WESTERN AUSTRALIA.

Die gegenwärtige Lage des Goldbergbaues in West Australien. By Dr. C. Schmeisser. *Zeitschrift für Praktische Geologie*, 1896, *page* 174, *with map.*

The area of the twelve West Australian gold-fields amounts to 296,225 square miles; these belong chiefly to the Central Australian table-land, characterized by its flat or undulating surface and the absence of hills of any importance. Granite forms the bed-rock of the gold-fields, and crops at the surface in flat bosses, as, for instance, in the Murchison district. It is overlain by stratified rocks, whose strike is south-south-east to north-north-west, with a steep dip, consisting in the main of clay-slates, quartzite, and quartzitic sandstones, which are often replaced by phyllites, talcose and chloritic schists. Important masses of diorite and diabase, both interbedded and eruptive, occur in the stratified rocks and in the granite. These eruptives are mostly highly decomposed down to depths of from 70 to 150 feet, as also is the granite in many cases. Dykes of felsite-porphyry also occur, but are of far less importance than those of diorite and diabase. In these formations a number of veins, beds, and alluvial deposits of gold occur. The veins mostly strike south-south-east to north-north-west or south-south-west to north-north-east, with a dip generally to the westward. The veins very largely run together in groups, but are sometimes isolated. Two kinds may be distinguished, compound veins or lode-formations and simple veins; the former are veins whose filling material consists of country rock more or less altered and traversed by bunches and strings of quartz. The latter are filled almost entirely with quartz. Those of the first-named class are confined generally to diabase and diorite, and these are very variable in thickness, in some cases exceeding 100 feet, but sometimes wedging out to nothing. The more strings of quartz traverse the vein-matter and the more spongy and shattered the quartz is, the richer is the vein as a rule. The foot-wall is generally the only well-marked one; on the hanging side the vein-matter gradually passes into country rock.

Simple veins are of very various thicknesses, from 1 inch to several feet. Their walls are generally well marked. They often form lenticular deposits. In the Edjudina vein group the veins almost exclusively consist of strings of lenticular masses of quartz.

Contact-veins are plentiful. Where veins traverse stratified country they generally appear as bedded veins.

All these veins may be looked upon as mineralized fissures, whose formation was often accompanied by faulting—generally normal, rarely overthrust—of the country rocks. In the case of compound veins, the pressure resulting from these movements has crushed and pulverized considerable portions of the wall rock, which was subsequently transformed into vein-matter by the action of mineralizing solutions. Numerous planes of slipping and slickensides attest the action of immense pressure.

The most important mineral is gold, which is practically confined to the quartz, generally so finely divided as to be invisible, but occasionally occurring in visible particles, ranging up to large masses, like that one, weighing 303 ozs. 10 dwts., which was found in the outcrop, at a depth of only 6 feet, in the Devon Consols claim at Black Flag. In dark coloured, brown and yellow quartz, the gold is mostly finely divided, but generally coarse in white or milk-white quartz.

The gold contents generally show enrichment in chutes, which always dip in the direction of the strike of the vein ; in such cases the chutes may be very rich whilst the vein outside the pay-chute may not be workable. Even within the chute, the gold is very irregularly distributed, very rich spots alternating with barren ones. It is, therefore, necessary to continually sample and test the veins in order to see which portions are sufficiently rich to be worked with profit.

Another fact, often noticed, is that the outcropping portions are greatly enriched, either in pockets or for a considerable length, so that completely erroneous estimates of the values of the veins may be formed On working in depth, the ore is found to get poorer, in cases even to complete barrenness. The accompanying minerals, besides a low proportion of silver, are in the deeper undecomposed portions of the veins, iron pyrites, arsenical pyrites, in places galena, and rarely copper pyrites. The depth to which decomposition has extended varies from 60 to 150 feet.

It is most important to ascertain whether the gold holds down in depth, and, especially, whether it continues in the pyritic undecomposed portions of the vein. In the present stage of imperfect development no decision can be arrived at, the deepest mines at date being :—

	Feet.		Feet.
Bayley's Reward	380	Great Boulder	200
Hannan's Reward	285	Ivanhoe	193
New Chum	240	Fortune of War	183

It has, however, been definitely observed that many quartz-veins wedge out at very moderate depths and distances ; it also seems doubtful whether the lenticular quartz-veins will continue in depth. Veins that extend to great distances generally go down far in depth, hence it may be hoped that such veins, amongst which many of the compound veins may be classed, will prove permanent in depth. There are few data to show how the contents of the veins will be affected in the pyritic zone. This has only been opened up so far in the 193 feet level of the Ivanhoe mine, where the vein consists of a quartzitic rock-mass carrying much pyrites and a not-unimportant amount of fine gold.

It may be added that the east-and-west veins are in all respects inferior to those coursing north and south.

Bedded deposits carrying gold, which seem to have been produced by the disintegration of older higher-lying outcrops and the embedding of the products in the decomposition-products of the country rock, occur and have been worked in places.

Alluvial deposits, sometimes of exceptional richness, have been found in nearly every gold-field. These were worked by dry-blowing, and may be looked upon as exhausted, so far as their coarse gold contents are concerned.

Other deposits have been worked by crushing in stamp-mills, in Otis, Huntingdon, or Panklast mills, collecting the gold, as far as possible, by amalgamation, and reserving the tailings for treatment by a leaching process. On Golden Bar, the attempt has been made to save water by dry-crushing, followed by cyanidation ; the tailings are said to carry only 2 dwts. of gold. The view is gaining ground that other methods, besides mill amalgamation, will have to be tried in order to economize water. In the northern and western gold-fields, enough water for milling purposes can generally be got at depths of 70 to 80 feet, but, in the south, milling can only be conducted with the greatest difficulty on account of the general absence of water. Experiments at Kalgoorlie have shown that the minimum water consumption is 240 gallons to the ton of ore, and then only by the exercise of the most rigid economy, and by submitting to a very heavy loss of fine

gold in the tailings. The rainfall is so small—6·54 inches in Coolgardie in 1895—that it does not seem probable that sufficient water can be obtained for working on a large scale ; the Government accordingly proposes to bring water from the Helen or the Murray river, but with fields so extensive as these it can only be the most important central points that can benefit by this scheme.

There is no coal on the gold-fields, but coal has been found on the Irwin and Collie rivers, as to the importance of which discoveries nothing can as yet be said. In the southern mining districts wood for timbering as well as for fuel is generally to be got in sufficient quantity. Power may have to be generated by the use of petroleum engines. It may be possible to generate electricity on the sea-coast by means of East Australian coal, and to distribute this to the various consumers.

The yield of gold in the various mines is very irregular, and varies between 6 dwts. and 16 ozs. to the ton of ore, the ounce of gold being worth about 76s. The cost of working cannot yet be fixed, and varies greatly. Some of the leading, and therefore the cheapest, working mines in the Murchison district gave their cost as 30s. to 33s. It will probably average between 30s. and 50s., but it is to be expected that this figure will come down lower as the fields are more developed. This may make it possible for many mines that cannot now be made to pay, to work at a profit, and may also enable mines to continue, whose ore will get poorer in depth, and which could not pay their way under such conditions with the existing working costs.

Numerous other considerations affect the valuation of these mines. Australian prospectors are perfectly well acquainted with the fact that the very rich pockets that often occur at the outcrop rapidly disappear in depth, and accordingly set about disposing of their discoveries as promptly as possible. The requisite expert's report is of course brilliant if he does not insist upon deep trial-shafts. Moreover, experts of very doubtful capacity and integrity are to be found on these gold-fields. Men of all trades, ranging from sailors to book-keepers, become experts with surprising rapidity as soon as they breathe the air of the gold-fields, and cases occur such as that of one of these experts who reported on a property entirely upon the strength of a picked specimen that was submitted to him.

As many of the deposits were judged by their rich outcrops, most exaggerated ideas of the value of many mines were formed. European mining companies would have Australian gold properties at any price, the Australian middlemen added disproportionate amounts to the original purchase price, European promoters thought that they could not fix the original capital too high, sub-companies upon whose properties no real opening up had been done, were formed with enormous capitals, and thus mines have been floated with important capitals, that could only pay if worked on a small scale and with the utmost economy, whilst the enormous capitals exclude the possibility of dividends in most cases. A crisis is unavoidable ; those undertakings that are based on good gold deposits will survive, even though with a great diminution of their capital ; the poorer mines will go down, perhaps for ever.

Nature has laid great difficulties in the way of West Australian mining. On the other hand, many deposits are of exceptional richness near the surface, which will not, however, continue in depth. Many mines that have astonished the world with their rich ores will have to be satisfied with a yield of 10 to 12 dwts. to the ton. It may, however, be expected that ultimately the considerable number of fairly payable properties will secure for Western Australia for a considerable period a good place amongst the gold producers of the world, but not the prominent position which many sanguine people have predicted for it. H. L.

THE REFRACTORY GOLD-ORES OF QUEENSLAND: THEIR SOURCES AND TREATMENT.

By E. A. WEINBERG. *Report of the Sixth Meeting of the Australasian Association for the Advancement of Science*, 1895, *pages* 257-265.

The term "refractory gold-ores" is intended to designate those ores which will not yield their gold, or only a small portion of it, to ordinary treatment by amalgamation on copper plates. Their occurrence in Queensland is generally either massive or distributed through the quartz, as auriferous iron, arsenical, and copper pyrites, as auriferous sulphide of lead, bismuth, antimony, and zinc, and, finally, as telluride.

Queensland is well provided with metallurgical works, which are able to deal with the refractory gold-ores of the colony. There are large chlorination-works at Mount Morgan, and on a smaller scale at Charters Towers and Ravenswood. There are general smelting-works at Aldershot, which are dealing with a large quantity of auriferous material, and the cyanide process is in operation at Charters Towers, Croydon, and Georgetown.

Barrel chlorination is the usual application of the chlorine process in Queensland, with the exception of the Charters Towers pyrite-works, which have always used chlorine-vats.

At Mount Morgan, vats holding about 25 tons of charge have replaced the barrels and smaller vats. Chlorine-water is applied, and it is claimed that the consumption of the solvent can be better controlled.

The report of the Mount Morgan works for the year ending May, 1894, placed the extraction at almost 95 per cent. of the assay value of the ore. The cost of chlorination, including milling and calcining, was about 15s. per ton.

At Aldershot, the auriferous pyrites, complex ores, etc., are being calcined, and the slagged material is afterwards smelted with roasted matte, oxidized lead ores and limestone in a blast-furnace, to a rich auriferous silver lead, which is partly refined at the works and partly sent to Great Britain. The extraction is very high, and the works guarantee 90 to 97 per cent. of the assay value at £4 per ounce, less £2 to £3 per ton for cost of treatment.

With the cyanide process, the average extraction, from 5 to 10 dwts. of ore, varies from 70 to 80 per cent., and under favourable conditions concentrates assaying from 3 to 4 ounces per ton yield 90 to 95 per cent. after 3 or 4 weeks' treatment. The strength of the first solution varies from $\frac{1}{4}$ to $\frac{1}{2}$ per cent.; the number and strength of subsequent solutions and washes depend on the quantity and nature of the ore. The average cost varies from 7s. 6d. to 10s. per ton.

M. W. B.

HAULAGE-INSTALLATION AT THE FUCHS COLLIERY, LOWER SILESIA.

Die neue Seilförderanlage auf dem Steinkohlenbergwerk cons. Fuchs bei Weisstein in Niederschlesien. By FR. STOLZ. *Glückauf*, 1896, *vol. xxxii., pages* 445-451.

The system adopted is that of a smooth, suspended endless-rope, $1\frac{1}{16}$ inch in diameter, and the breaking-strain 62½ tons per square inch. The hauling roadway is 6,400 feet long, beginning some 160 feet from the Julius shaft, and has six curves, the sharpest, of 11 feet radius, being at the junction of the first cross-heading with the main roadway. There are eight branches, at each of which a

double gradient is arranged, so that the tubs can be automatically released from the cables and pass into the side roads as required, and a similar arrangement is provided on both up and down lines at the sharpest curve to allow the tubs to run freely round the corner. Guard-rails are fixed in the curves, but curve-rollers are dispensed with, a considerable saving in wear and tear being thereby effected. The outer rails in the sharp curve are raised about 2 inches higher than the inner rails, but in the other curves the inner rails are the higher by between 0·10 and 0·40 inch.

The 50 horse-power, two cylinders, condensing engine is placed at right-angles to the roadway, and drives the hauling-drum by a double-set of bevel gearing. The rope pulley, placed vertically, is 7½ feet in diameter, and has but one groove, which is lined with hemp, this arrangement being considered preferable to differential pulleys, the hemp lining protecting the cable and allowing it to slip in case any of the tubs get off the rails. It also allows the weight of the slack rope tension to be reduced in the present instance by about half a ton. The pulley at the extremity of the system is mounted on a four-wheeled carriage running on nearly 30 feet of rail, so that double that quantity of stretch in the cable can be compensated. The actual stretch after nine months' working is about 20 feet.

The empty tubs are hauled from the shaft by a drag-rope and allowed to engage (by a V-clip on the front of the truck) on the cable at intervals of about 60 feet. After passing the sharp curve, a certain number of tubs are turned off into each branch by raising the cable by means of movable rollers, their places being filled by the full tubs waiting in the branch. As soon as each branch has received its complement of empty tubs the roller is lowered and the succeeding empty tubs pass on. At the far end, the transfer to the up-road is effected by three men, and, the haulage being continuous, 2,400 to 3,000 tubs can be handled in a ten hours' shift by a total staff of twelve workpeople, including the engineman. On arriving at the end of the up-road, the full tubs are released from the cable automatically and run down an incline to the shaft, the clips being removed and fixed on empty tubs.

The advantages claimed for this system are, that the exchange of tubs at branches can be effected in each case by one man. A considerable rate of speed—about 300 feet per minute—is attained, and the rolling stock can be kept at a minimum, only 194 tubs being required on the cable at one time. The high speed and small number of trucks allow of a light cable being used.

All things considered, this smooth-rope system without curve-rollers allows greater difficulties to be surmounted than can be overcome by the chain system with curve-rollers. The cost of making the curves of such radius that the tubs can pass without being released from the cable is little, if at all, greater than that of the rollers, and the heavy item of repairs is avoided. Another advantage of the system is that the cable need not be at such high tension as where rollers are used, and is therefore subject to less wear from friction. It is, however, necessary to prevent the cable, moving in one direction on the curves, from coming into contact with the cars moving the other way, and this may be done either by means of a partition of pillars between the up and down lines, or by keeping a sufficient number of tubs on the cable, *i.e.*, maintaining a regular interval of distance between the tubs throughout. This object is effected by keeping some forty tubs in readiness at No. 7 branch, and adding them as required to the general circulation. When there are no full tubs ready, the haulage is stopped by signal; but such interruptions may be avoided by fixing the percentage of tubs to be removed at each branch, and keeping a sufficient number in readiness.

All the branches are connected with the engine-room by electric signalling apparatus, and telephonic communication is also installed, so that any mishap can be promptly and clearly indicated, the current from the 18 Leclanché cells in the engine-room being strong enough to actuate the whole of the 8 bells in the roadways at once. C. S.

ENDLESS-ROPE HAULAGE AT THE ROLAND COLLIERY, RHENISH PRUSSIA.

Die machinelle Strecken-Förderung mit überliegendem glatten Seile ohne Ende im Hauptquerschlage der III. Sohle der Zeche Roland, bei Oberhausen. By W. BENTROP. *Glückauf*, 1896, *vol. xxxii., page* 413, *with drawings.*

The high cost, slight duty, and clumsiness of horse haulage, with expensive repairs to the tubs and renewals of the way, in the northern main cross-cut of the third level (which has a good roof throughout) of the Roland pit, led to the adoption of mechanical traction.

The cross-cut, 4,000 feet long, averages 6½ feet high by 7¾ feet wide; and the gradient varies generally between 1 in 100 and 1 in 160. The gauge of the rails is 20 inches, and the distance between the centre lines of the two tracks is 3¾ feet, so that there is a free space of 2 feet between the centre lines of the inside rails, thus permitting the passage of workmen between the full and empty tubs. The rope is worked by a steam engine, with two cylinders, each 8¾ inches in diameter and 13 inches stroke, which is geared so as to drive a horizontal pulley, having two grooves lined with hemp, the rope being kept taut by a suspended weight. In the cross-cut, the rope is carried by 53 Hasenclever rollers, keyed on inclined spindles, for the full and empty tubs. The round rope is ⅛ inch in diameter, consisting of six strands, each formed of eight steel wires and three soft iron core-wires, and also a hempen core, the breaking strain being over 13 tons. The maximum duty is 95 full tubs, weighing 16 cwts. each, and the same number of empty tubs, weighing 6 cwts. each, so that the strain on the rope does not exceed 1·35 tons. Adding to this 25 per cent. for other losses by friction brings up the work at the circumference of the driving pulley to 1·70 tons.

The cost of hauling a ton per mile is about 1½d. J. W. P.

AXLE-BOX FOR MINE TUBS.

Note des mines de La Chapelle-sous-Dun. By — GARDON. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1895, *page* 274.

It being essential to double the output of the Saint-Louis shaft of La Chapelle-sous-Dun colliery, and at the same time to reduce the actual time of winding to 7½ hours, in order to preserve the eight-hours day, it was only by modifying the plant, so as to hasten each operation, that such a result could be obtained. Among the improvements adopted was a tub wheel containing an axle-box of large diameter, a cover that could not come unscrewed, and with a reservoir that would avoid loss of oil at the tipplers, and when tipping the tubs on their side for unloading gobbin or large coal.

The problem of rendering the joint unaffected by shock, preserving it for inspection, and allowing of the cleaning of the box is, it is believed, solved by the arrangement adopted, in which the box is made to project considerably beyond the

end of the axle, and sunk at the outer end so as to receive the cover. The latter is attached by a single bolt; and the joint is made with a washer of refuse india-rubber, leather, or asbestos. Since this box has been adopted, the haulage over bad and muddy roads, with a floor that often heaves, has been greatly improved, while considerable saving is effected in oil as well as in wear-and-tear.

J. W. P.

BRAKE AND PULLEY FOR SELF-ACTING INCLINES.

Poulies de Plans inclinés automoteurs. *By* PROSPER VANHASSEL. *Revue Universelle des Mines, etc.*, 1895, *vol. xxxi., page* 232, *and figures.*

In 1887, with a view to reduce the number of accidents that occurred on self-acting inclines, the Belgian Mine Administration enjoined mine-owners to use pulleys, either with a screw-brake or with a brake normally kept on, and only taken off during the action of raising and lowering tubs.

With the view of complying with the injunction of the Belgian Mine Administration, the author has invented a pulley consisting of (1) a frame formed of two flat steel bars, which not only keep the wheel in place, but also clamp the sides of its rim after the manner of a brake; (2) a cast-steel grooved pulley, the shaft of which revolves in holes in the bars of the frame and in steel-boxes bolted thereto; (3) two right and left-handed screws, arranged parallel with the pulley-shaft and on either side of it, for bringing nearer together or separating the two bars of the frame, according as it is desired to put on or take off the brake; and (4) two levers for working these screws, connected together by a link, so that one movement works both screws.

The new pulley simplifies and lightens the work of the brakesman, as about a pound's pull on a lever of 4 to 6 inches is sufficient to ensure stoppage. The parts are all interchangeable, the construction is simplified, maintenance and repairs are facilitated, and the first cost is lessened. The weight of the pulley is greatly reduced, thus exerting a favourable influence on its transport and erection, while this latter work is simplified by the fact that the pulleys have both sides alike; and at the same time the fatigue of the brakesman is diminished and the general safety increased.

J. W. P.

BALANCE WITH WATER-BRAKE FOR LOWERING GOB MATERIAL.

Balance hydraulique de Saint-Eloy. *By* — BAUDREY. *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1895, *page* 272.

In the north pit of the Saint-Eloy collieries, it was required to lower a mass of gob material, weighing from 1·2 to 2·5 tons per minute, to a depth of 540 feet, at a mean speed of 13 feet per second, the resistance opposed to the maximum descending load of 2½ tons, acting as motor, being therefore 133 horse-power. The ordinary balance with drum and strap-brake, the Villiers air-brake, and methods for utilizing the force given out by the descending weight in compressing air or forcing water, were rejected, the following arrangement being adopted.

On a drum, 9 feet in diameter, two ropes, 1$\frac{1}{16}$ inches in diameter, are alternately wound up and unwound, the drum-shaft, carried by two plummer-blocks, having cranks at each end, keyed at right angles, each coupled with a connecting-rod to the piston-rod of a cylinder or pump-barrel. The piston-rods pass through both cylinder-covers, tightness being ensured by cupped leathers and water joints; and each barrel (the two being identical) is 13¾ inches in diameter, with a stroke of 39⅜ inches. The fore and back ends are connected, both by a passage at the

side and by two pipes passing over the top, each of the latter being provided with a valve, so arranged that one shall rise at the forward and the other at the backward stroke of the piston, and both being kept down on their seats by a spiral spring that can be regulated by a set-screw. The side-passage between the ends of the cylinder has in the middle a shut-off valve worked by a wheel and helicoidal screw, of which latter about five turns are required for complete closing, this arrangement being adopted with the object of avoiding the shock that would occur with sudden closing. When the barrels and pipes are full of water, the load to be let down is loaded on to the cage, and the signal given to the brakesman, he opens the shut-off valves, when the pistons move in the barrels, causing the water to pass simultaneously from the fore to the back end and inversely, the opening of the shut-off valve being regulated so as to give a speed of 13 feet per second, while a partial closing slackens the speed, and total closing brings about stoppage. The water, which soon becomes heated by being churned in the cylinder and wire-drawn in the pipes, is renewed from a supply at a higher level, entering the cylinder at the under part, to leave it by the pipes over the top, the inlet and discharge-valves being worked by levers within reach of the brakesman, so that the water can easily be changed between two lifts. A powerful brake is held in reserve in case of need.

Calculation of the diagrams taken with variable loads gave the following results:—With two empty tubs, weighing with the rope 1 ton, going down at a speed of 13 feet per second, the resistance to be opposed is 54 horse-power; with one tub filled with gob and one empty, 74 horse-power; and with both tubs filled with gob, the resistance arranged for, viz., 133 horse-power.

J. W. P.

ROASTING IRON AND MANGANESE ORES.

Note sur le Grillage des Minerais carbonatés de Fer et de Manganèse. *By* S. JORDAN. *Revue Universelle des Mines, de la Métallurgie, etc.* 1895, *vol. xxxi., page* 1.

The roasting of iron and manganese carbonates does not constitute a simple calcination merely; but in order that the operation may be complete after the carbonic acid is set at liberty, the remaining protoxide should be transformed into peroxide as regards the iron, and into red oxide as regards the manganese, on account of the further treatment to which these ores have to be subjected. The super-oxidation of the protoxide develops a quantity of heat greater than that absorbed in the volatilization of the carbonic acid, so that the complete roasting of iron and manganese carbonates is effected, theoretically, without expenditure of heat. Consequently such ores should be roasted without consumption of fuel: *i.e.*, the operation should continue by itself, when once started, if these ores were pure and did not contain earthy carbonates, which require more heat for their decomposition, or water that also absorbs heat for its vaporization. The following are the conditions according to which carbonated iron ores are roasted in an oven with shaft like a blast-furnace, fired by small coal.

The layers of ore, alternating with a small proportion of fuel—¼ per cent. for instance—should first descend evenly over the whole horizontal section of the oven into a preliminary decarbonatation level (*étage*), becoming heated progressively by contact with the upward gaseous current. Arrived at a certain depth, the ore meets a zone heated to 400 or 500 degrees Cent., where it commences to lose its carbonic acid, and afterwards arrives at the zone of combustion, or region where the slight proportion of coal is quickly burnt by the very hot air from the bottom of the oven, thus raising the temperature sufficiently to complete the driving off of

the carbonic acid. Here the coal only diminishes slightly; but below the zone of combustion, merely the ash remains. The ore should continue to descend—becoming looser rather than tighter—at the superoxidation-level, in the midst of an afflux of air arriving through the whole horizontal section of the oven. This air, entering through the openings made for discharging, and also by the hearth, is gradually heated, as it rises, by contact with particles of calcined ore, either through their own temperature, due to passage through the upper level, or through the superoxidation of the protoxide. The air, having at the same time lost a little of its oxygen, reaches at a high temperature the zone of combustion where, notwithstanding its loss of oxygen, it soon burns the fuel encountered. The ore will arrive at the bottom of the oven completely superoxidized if the influx of air be sufficient, and slightly cooled and having regained the consistency which it had to a certain extent lost through the loss of the carbonic acid. If the influx be insufficient, however the ore will reach the bottom imperfectly superoxidized, more friable and at a temperature which may render its discharge very difficult.

Instead of too large a proportion of fuel effecting a better roasting as the zone of combustion is larger in such a case, the protoxide has not so much space for becoming superoxidized, but arrives still hot at the discharging-point, while the yield may diminish. This cannot be remedied by increasing, through a more rapid discharging, the speed with which the materials descend; indeed, it may be necessary to delay the discharge, and therefore diminish the production of the oven. The quantity of air which enters below cannot be increased or diminished at pleasure except by complications in the kiln; but care must be taken to prevent the air-inlets from being obstructed by dust or pieces of ore, in which case the combustion will not be complete at its proper level, the atmosphere of the lower part of the oven will cease to be sufficiently oxidizing and the ore will arrive at the discharging-point too hot and imperfectly roasted. J. W. P.

A MINE OWNED AND WORKED BY MINERS IN FRANCE.

Etude administrative sur les Mines de Rancié. By — VILLOT. *Annales des Mines*, 1896, *vol. ix., page* 205.

"*La mine aux mineurs*" expresses, according to some persons, the idea towards which progress should lead future generations in the working of mineral wealth. French mining legislation is in no way opposed to a mining royalty being conceded to working miners; but the words quoted above suggest the raising to the height of a new principle the fact that the miner, when extracting the mineral from the depths of the earth, then and there takes possession thereof. It so happens that, owing to various and special circumstances, a few cases exist in France where mine workings approach more or less closely to this ideal state of things; and the most remarkable is that of the Rancié iron-mines, in the department of Ariège. Owing to their very long existence, to the successive modifications tried for warding off the difficulties of which they have been the scene, and specially to the last modification that has been carried out quite recently, it appeared to the author that their history would convey a lesson of the greatest importance, while bringing forward some curious episodes both technical and administrative.

The author describes the nature of the Rancié deposit, and traces the various vicissitudes undergone by the mine from the charter of 1293 to the law of February 15th, 1893, with the principal provisions of the decree of April 24th of the same year. The author concludes that liberality ill appropriated to the condition

of those on whom it is bestowed may prove the source of their misfortunes; that all property made over to a group of individuals will be endangered unless, for turning it to account, a competent and responsible authority be constituted for its administration in the common interest; that the law of supply and demand is not nearly becoming obsolete; and that, as soon as a mine becomes at all important, it cannot dispense with capital, which has been truly defined as representing the accumulation of work.

J. W. P.

RESPONSIBILITY FOR DAMAGE CAUSED BY INDUSTRIAL ESTABLISHMENTS IN FRANCE.

De la Responsabilité des Dommages causés par le Voisinage des Établissements industriels. By LÉON MICHEL. *Bulletin de la Société de l'Industrie Minérale*, 1895, *vol. ix.*, *page* 847.

Every owner may erect works on his own land; but, for avoiding abuses, industrial establishments are divided by French law into three classes, while the owner must obtain previous authorization, which, however, does not prevent a third party from entering an action for indemnity. In order that the civil responsibility of the owners of industrial establishments be admitted, the damage must be serious, and exceed what is generally tolerated in a manufacturing town. The principal nuisances resulting from the existence of industrial establishments are noise, smoke, bad smells, or emanations, and the pollution of water. The danger of fire or explosion gives no right to indemnity, because it constitutes a purely eventual damage; and the mere presence of an industrial establishment does not afford ground for damages. By article 9 of the decree of 1810, an individual building in the neighbourhood of manufactories and workshops, after their erection, is debarred from applying for their removal; but this provision does not deprive the owner of a building from the right of claiming indemnity for the damage caused by the works, while the enhanced value of his property, owing to the existence of the industrial establishment, must be taken into consideration as a set-off in estimating the damages. Actions for indemnity must be brought before the civil tribunal, which cannot order the suppression of an authorized establishment, although the judges can, under certain conditions, prescribe the execution of works for abating the nuisance complained of. The injury caused is generally compensated by a yearly payment; but in some cases the court may allow a lump sum by way of compensation.

J. W. P.

EFFICIENCY OF A LOCOMOTIVE ENGINE WITH SEPARATE STEAM AND EXHAUST-VALVES.

Note sur les Essais comparatifs faits à la Compagnie d'Orléans sur une Locomotive munie de la Distribution à tiroirs, d'admission et d'échappement indépendants, et sur une Locomotive avec Distribution à tiroir à coquille. By ERNEST POLONCEAU. *Annales des Mines*, 1895, *vol. viii.*, *page* 651.

The author made comparative haulage-trials, in September and October, 1894, by two dynamometer-waggons on locomotive No. 332 with four valves, and No. 337 with ordinary slide-valves, drawing, sometimes one and sometimes the other, twenty-four trains running backwards and forwards between Paris and Orléans, every possible precaution having been taken to avoid error in the observations.

The expenditure of steam per horse-power per hour by locomotive engine No. 332 (with four valves), measured at the tender draw-bar, was found to be 11·19 per cent. less than that of engine No. 337 (with ordinary slide-valves); and the quantity

of coal consumed by the former engine was 6·3 per cent. less than that consumed by the latter, a weight of 1 pound of coal having generated 8·17 and 7·81 pounds of steam respectively in the two locomotives, which are absolutely identical, except as regards the valves. The separate valve arrangement has the additional advantage of permitting the engine to run at a greater speed, and also to get up speed more quickly. The locomotive with four valves, drawing a mean load of 167 tons, often attained a speed of 67 miles per hour, which was never attained by that with ordinary slide-valves, the former having frequently made up lost time, while No. 337 engine could not gain a single minute on a run of about 20 miles.

In the cylinders, the mean work done by 1 pound of steam was, for No. 337 engine, 102,967 foot-pounds, and for No. 332 (with separate valves) 113,400 foot-pounds, showing a general saving by the latter of 9·2 per cent. These results agree very nearly with those obtained by the dynamometer-waggons, which show a saving of 11·19 per cent. effected by the four-valved engine, but for the whole run of the train, which includes work done by the steam at full admission as well as with early cut-off, while it was anticipated that this latter case would alone show any appreciable saving.

These experimental trials were made with engines whose boilers were both worked at a pressure of 142 lbs. per square inch, which was scarcely ever exceeded a few years ago; but, now that much higher pressures are employed, there is little doubt that far greater savings may be effected with separate admission and exhaust-valves, while the mere fact of increasing the above-named pressure by one-half ensures an economy of 14 to 15 per cent. J. W. P.

METHODS OF TESTING MATERIALS.

Conclusions de la Première Section de la Commission des Méthodes d'Essai des Matériaux de Construction. Annales des Mines, 1896, *vol. ix., page* 468.

The French commission on methods of testing building-materials was appointed by decree in 1891, with the mission of formulating uniform rules to be adopted in the testing of materials, and of determining the units to be taken as terms of comparison. This commission was divided into two sections: one charged with investigations relating to metals, and the other with those concerning materials, other than metals, such as enter into the constitution of masonry work. Both sections have published valuable treatises, and also general reports. The propositions of the commission have been accepted by a large number of administrative bodies; and its prescriptions now find a place in many specifications.

The first section, in drawing up its conclusions, has made a point of keeping to an examination of testing methods, which forms the programme of the commission's labours, carefully avoiding the emission of any opinion as to the conditions to be imposed, so as to leave both producers and consumers perfectly free in this respect. While studying the various methods of testing, the section has also thought well to show no preference for any one method for a given application.

The first part, on physical tests, is divided into—(1) physical examination; (2) determination of physical constants; (3) physical study of variations in the condition of metals under changes of temperature; and (4) hardening. The second part, on chemical tests, contains –(1) analysis of metals and alloys; and (2) corrosion and adherence tests of protecting coverings.

The third part, on mechanical tests, with recommendations common to all test methods, contains:– (1) general observations; (2) preparation of test-pieces; (3) influence of temperature on the results of tests; (4) influence of duration on the

results; (5) general observations on testing apparatus; and (6) examination of the quantities to be measured, as to which the following observations may be quoted: —(*a*) In a complete test it is advisable to record the strains and deformations corresponding with the two characteristic periods which occur in every test effected with continuous action, viz., elastic and permanent deformations; and (*b*), as regards the elastic period, the three following limits are to be distinguished:—(a^1) the limit of elasticity when the deformations cease to be instantaneous; (b^1) the proportional limit of elasticity, or limit of proportional deformations corresponding with the point where the deformations cease to be proportional to the strains; and (c^1) the apparent limit of elasticity, or starting-point of the deformations under a constant load, corresponding with the point where the deformations acquire an increasing value without increase of the effort exerted. The remaining chapters of this part deal with (7) mechanical and (8) technical terminology.

The fourth part, on mechanical tests, with a detailed study of the various methods, is divided into five classes, each subdivided into chapters: the first class comprising test methods with graduated action; the second, test methods with sudden action; the third class, hardness and fragility; the fourth, workshop tests; and the fifth, special tests of certain finished parts. J. W. P.

OCCURRENCE OF MERCURY IN THE ASTURIAS, SPAIN.

Le Mercure dans les Asturies. By A. Dory. *Revue Universelle des Mines, de la Métallurgie, etc.*, 1895, *vol. xxxii., pages* 209-247, *and* 5 *plates.*

A large portion of the mineral wealth of the Asturias consists in its production of mercury, which was nearly 4,000 flasks in 1893.

Various theories have been promulgated to account for its origin. At La Peña in Mieres (Asturias), the ore occurs in a breccia at its contact with the upper schists and quartzites of the Mountain Limestone; at Pelugano, the deposit occupies a fissure, of which the Mountain Limestone forms the hanging- and Devonian quartzite the foot-wall; at Lada, cinnabar is found impregnating three seams of coal and Carboniferous conglomerates; whilst at various other places in the province, red cinnabar, accompanied by a very rich black sulphide (metacinnabarite) realgar, orpiment, and metallic arsenic, occurs in limestone, in sandstones, and in metamorphic schists. The author considers the mercury to have been deposited in some cases by water circulating in rock-fissures, and in others by currents of gases and metallic vapours which condensed in pre-existing cavities.

The method of treatment consists in roasting the ore in furnaces of various types, by which operation metallic mercury and sulphurous acid are produced. Several kinds of furnaces, differing more particularly in their condensers, are employed in the Asturias; the older forms, the Aludel furnace, the Idrian furnace, and the Pipe furnace (Rivermore), all of which work intermittently, are being gradually replaced by two forms of the Rodriguez furnace, which work continuously, and show a far smaller loss of mercury.

Together with mercury, an arsenical fume is deposited in the condensers; it is washed, when it contains 62·78 per cent. of arsenious acid and 14 per cent. of mercury, and is redistilled, which latter operation brings its richness up to 90·73 per cent. of arsenious acid and 8·6 per cent. of mercury. H. L.

SELF-ACTING WAGGON-TIPPLER.

Selbsthatiger Druckwasser-Kohlenkipper (System Schmitz-Rohde). CENTRALBLATT DER BAUVERWALTUNG. *Glückauf*, 1896, *vol. xxxii., page* 661.

The Krupp hydraulic tippler, for tipping the contents of coal-waggons into barges at the Ruhrort and Dortmund harbours, is capable of tipping from 120 to 150 ten or fifteen-tons waggons in a day of ten hours. The work given out by the loaded waggon when being tipped is stored in an accumulator, and utilized for bringing back the empty waggon, while the work of tipping involves no expense, as no other power is used. All the coal and coke waggons of the Royal Prussian and German State railways, with their various brake arrangements, and with wheel bases varying from 8½ feet to 14¾ feet may be tipped, without making any change in waggon or tippler, provided the former have a movable end.

The tippler consists of a platform turning on a horizontal axis, and having in addition a fixed working-floor, from which nothing projects except the lever of the regulating-valve for turning the platform, and holding it fast at any desired angle between 0 and 45°. The front of the platform, provided with a wide shoot, narrowed however to a smaller width on the water-side, is supported by a plunger moving in a cylinder, which latter is always under pressure. Glycerine is added to the water for protection from frost; and the cylinder is, with its accumulator and regulating-valve, enclosed in brickwork, being thus protected from dust. On a loaded coal-waggon being run on to the platform, the flanges of its front wheels press upon a clamping arrangement provided with two powerful hooks, held up spring fashion, which grasp the front axle and hold it fast in the desired position. During this movement, the regulating-valve is closed; and, as the platform is held fast in this position, its safe working is ensured. It is, indeed, only after the opening of the valve that the platform, with its shoot, begins to tip. The water under pressure rises in the accumulator during the descent of the plunger, and lifts the counterweight to a height corresponding with the inclination. The coal then falls through the open end of the waggon on to the shoot, and so into the barge. J. W. P.

ORE-CONCENTRATORS.

(1) *Neuerungen im Aufbereitungswesen. By* L. KIRSCHNER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, *vol. xliii., page* 91.

In this paper the author calls attention to the improvements lately made in the Rittinger table for concentrating coarse ore. For separating equal-falling sands already classified in water, the surface-dimensions hitherto employed in this table were known to be larger than necessary. Formerly two tables, each 3 feet 7 inches wide, and 7 feet 8 inches long, were placed in one frame; the length has now been reduced to 4 feet 2 inches, without affecting the purity of the concentrates. This modification has diminished the weight of the apparatus, which has been further reduced by substituting wooden frames, weighing 350 lbs., for cast-iron. weighing 2,800 to 3,000 lbs.; less motive power is consequently required. The advantage of the smaller and lighter table is that 300, instead of 100, lateral bumps can be imparted to it per minute; 308 lbs. of sand can be concentrated per hour, instead of 286 lbs., and the output of slick increased from about 12 cwts. per month to 65 cwts., or 5½ times as much. The consumption of water for washing and concentrating the slimes was formerly 26½ gallons per minute, it is now less than 14 gallons. Thus remodelled, the Rittinger side-bump table can be

used for concentrating coarse sand, its efficiency has been improved, defects remedied, and, in the author's opinion, it may now compete successfully with the best foreign types, both in regard to the quantity and quality of ore treated.

The horizontal surfaces for dressing the ore have also been divided. The buddle now consists of three small wooden tables, each 4½ feet wide and 3¼ feet long, arranged in stages, and having the same area as the Salzburg end-bump table. By this arrangement the ore is not shifted, and time and labour are economized. The three tables are ranked in steps, one below the other, corresponding to the three classes of concentrates. The silver-bearing lead-ore on the uppermost table is carried off to a launder, the intermediate products on to the second table, and the tailings to the third. This improved apparatus, drawings of which are given in the original paper, is called a "repeating table," because the ore is washed successively at each stage. It is made in duplicate, with six tables in all, in pairs, side by side, two on each level; they are supported on wooden props and iron cross-pieces, and the blow is imparted to each by a cam. The six cams are set at an angle of 60 degrees on a common shaft running the whole length of the frame, driven by a belt and pulley, and carrying a small fly-wheel. The two highest frames receive the thrust direct from the shaft, the four lower by means of levers and rods. The cams act on the three tables on the further side through connecting-rods, and each table is brought back into position by a buffer spring. The wash-water is supplied through grooves and pipes surrounding the frames, and is discharged from each level through grooves parted off into divisions. The slimes are fed to the tables by a Rittinger pump, and are first passed through a brass wire-sieve, with 80 holes to the inch. This classification is necessary, to prevent any but the finest slimes from reaching the tables.

The slime is first conveyed to the highest table, where it mixes with the wash-water, and is concentrated. The sulphide of lead is carried off to the slick-receiver, and the intermediate products to the second table, some of the water being drained off in a leaden reducing-vessel. The tailings are treated in the same way, and after being reduced are led off to the third and lowest table. On the second table, where the intermediate products from the first are concentrated, lead-ore, mixed products, and tailings are again separated, and the same process is repeated on the third table, unless the ore is very poor, when all, except the lead-ore, is thrown away. To treat the ore thus wasted, a fourth table might be added, but this would increase the size of the apparatus, as a greater fall would be required. From ⅓ to ½ horse-power is required to drive the set of tables, and the power does not vary, as in the Salzburg table, where more is needed according to the thickness of the bed of ore.

If instead of adapting existing frames, a new apparatus is set up, all the frames should be of wood; as no foundation is required it is cheap and easy to fix. According to the experiments, a double set of tables will deliver per hour 440 lbs. of sorted ore, passed three times through a jig, or 340 lbs. if the intermediate products are concentrated a second time; the latter is the quantity usually reckoned in a Salzburg end-bump table. The total concentrates yielded 51·5 per cent. of silver, and 69·3 per cent. of lead, with traces of silver and lead in the tailings, the small percentage of loss being due to the floating particles. Comparative experiments made on the Salzburg and Rittinger tables showed that the output of concentrates from the latter was larger. The principal advantages of the new type are: simple and cheap construction and fixing; less attendance required, one man being able to work two sets of tables; automatic supply and more complete concentration of the ore; diminished consumption of water and less motive power.

B. D.

(2) *Die Aufbereitung der Schlämme.* *By* JULIUS SCHWARTZ. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, *vol. xliii.*, *page* 681.

The author of the second paper follows up a previous article* upon the Bartsch round percussion-table. Four of these have been working without intermission since 1893 at the gold-mines at Kremnitz, in Hungary, and they have also been introduced into other gold-mines in Upper Hungary and Transylvania. Since 1894 they have been further improved and modified, and may now be considered to have reached their final stage.

The principle of the Bartsch apparatus is that of a convex non-rotating table, over which the slime and wash-water distributors revolve, and which is continuously bumped. To produce the radial blows, it is pushed round by a cam, drawn back by a spring, and strikes sharply against two projections in the outer circumference. The blows, 80 to 150 per minute, follow rapidly and are delivered direct from the base: their effect is to cause the ore to separate according to weight in horizontal ridges along the slope, following the parabolic line of the water-distributor. The heaviest ores collect thickly in front of the distributor. This result, which cannot be produced in any other way, may be verified by placing a piece of iron on the table. Although the latter is about 13½ feet in diameter, the motion imparted to it is quick and easy. Attempts have before been made to impart blows to a circular table, but the Bartsch is the only one in which the idea has hitherto been realized. Important improvements have, in the author's opinion, been thereby effected in the dressing of ore.

In the careful experiments made at the Lohmannsfeld mine at Neunkirchen, the mixed lead products were continuously concentrated. Wet samples of the different concentrates were constantly taken, the slimes allowed to settle, and the clear water gradually drained off. The thick semi-fluid slime residuum was then steamed and tested by the wet process for lead and zinc. The slime and water being drawn off together, the results obtained corresponded to those in actual practice. Samples of raw slimes were taken in the usual way, before they passed to the table. As they came from iron-spar containing lead and zinc, only spathic blende (lead slick) and waste could be concentrated, and not blende slick. The spathic blende might easily be separated at the mine, by an electro-magnetic process, if the spathose slimes were mixed with some granular substance. As iron-spar and blende are of the same specific gravity, to concentrate the zinc-ore it is only necessary to separate the lead-ore and tailings.

With the four Bartsch concentrators in use at Kremnitz, it was found that the finer the slimes the more regular was the yield. The ore is twice sifted and the sand separated, then passed through five jigs, and the slime reduced to medium and fine meal. The former is concentrated on two tables with a greater, the latter on two others with a less slope. The clearness of the water flowing from the pointed boxes shows that the finest slimes are concentrated on the tables. With medium meal, the slime and wash-water distributors should rotate more rapidly over the table than when fine meal is treated, and the blows delivered should be longer. Experiments made with slimes from the same mine on a Stein buddle yielded unsatisfactory results.

Only fine or medium meal ought to be concentrated on the Bartsch table, if they come from the dressings of coarse ore, but larger slimes and meal up to $\frac{1}{50}$ inch in size can be treated, if previously crushed. With gold-bearing ore, the barren rock always breaks into coarser, the ore into finer pieces, and as the former

* *Trans. Fed. Inst.*, vol. ix., page 494.

are swept first from the table, they do not hinder the concentration of the fine ore. The crushed ore varies constantly in size, but is usually so fine that it can only be treated on a table such as the Bartsch, which will concentrate both the coarser meal and fine slimes, if properly adjusted. The adjustment is effected by regulating the number of bumps, and the speed of revolution of the table (which is from ¼ to 1 revolution per minute, and not 20 revolutions, as erroneously stated by the author in his former paper). The consumption of wash-water per table is 11 to 15½ gallons per minute with fine slimes, 15½ to 22 gallons with medium, and 22 to 30 gallons with heavy ores. The delivery of the blows is a special feature of the Bartsch table. One authority suggests that more wash-water should be used in place of the bumps, but the best results, even with moving tables, are obtained with least water. More water, especially in gold-mining, means more waste, more intermediate products, and fewer rich concentrates. If the table be not bumped, the water carries off much fine slime, but this does not happen with the Bartsch concentrator, where the blows reduce the quantity of water, and any fine meal sucked up by the action of the distributor is again deposited. The finer the slimes, and the less resistance they offer to the water, the greater the necessity for the bumps.

The author next criticizes experiments made with a Schranz table, and maintains that trials are only of real value if carried out on a uniform system, with the same slimes. In these experiments, the slimes were evidently easy to dress, and from the large concentration of blende they contained very little spathic iron. At Lohmannsfeld, the iron in the slimes is 25 per cent. The samples tested were taken from the lower tables, and did not give the correct amount of waste. Much depends on the method of taking these samples, that they may truly represent the proportion of ore still left in the tailings after passing through the tables. The results obtained with the Bartsch table are, in the author's opinion, more reliable, and the bump imparted more effective than in the Lang and Rittinger buddles.

Other tables used in Germany are the Schranz, which is becoming obsolete, the Stein, and the Lührig; the latter has not been found very successful, even when made compound, because the ore is not sufficiently concentrated, and the tailings are too rich. It is also delicate to handle, and complicated. Many of these rocking-tables will not pay for working, the surfaces being too small to treat poor ore satisfactorily, although the coarser ores are well concentrated. As they are less than half the size of the Bartsch, the barren rock from them must be richer. Another advantage possessed by the Bartsch is that the bump only shakes the table and the base, and does not affect the distributors. In the Stein, Lührig, and frue-vanner tables, all the moving parts are exposed to the action of the blow. The delivery of ore from the Bartsch table is also much larger, although more tables are used with the Lührig system than ought to be required for the normal output of 220 lbs. per hour per table. More attendance is necessary, and the tables are apt to become clogged. The Linkenbach table is conical, like the Bartsch table, but has no bump, and is much larger, although it yields the same quantity of tailings. It has been superseded by the latter in Upper Silesia, and both in the Transvaal and Upper Hungary it is no longer used. For fine slimes a stationary table of large area will not concentrate sufficient ore, as much water is required, which washes away the slimes. The Bartsch table appears specially adapted for concentrating fine gold slimes in South Africa, and arrangements have already been made to introduce it into that country. B. D.

OBEREGGER COAL-SCREEN.

Der Klassir-Apparat von A. Oberegger. By V. Waltl. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, *vol. xliv., page* 628, *and illustrations.*

In most of the screens used for sorting coal and other mineral the sieves are arranged one above the other, and enclosed in a box. Thus they are not easily accessible and cannot be seen. By placing them in stages, and interposing troughs to receive the coal as it falls, the height and weight of the screens are increased, and the coal after screening is discharged with difficulty. The arrangement is costly, requires a strong foundation and large ground space, there is frequently much vibration, the foundation-bolts are exposed to the dust, and the mechanism difficult to lubricate. In most screens also the driving-pulleys are close to the ground, and it is impossible to pass between them, while with reciprocating-screens the frame and base are noisy, and rapidly worn out by the repeated blows.

The author describes a new screening apparatus designed by Mr. A. Oberegger, which can be adapted to various sizes of coal, and avoids the defects of other screens. The sieves are grouped in tiers round a square or polygonal box, through the centre of which passes a vertical shaft, driven by worm-gear from above. The sieves overlap, but each is independent of the other. The apparatus is suspended by four chains working in sockets to a beam overhead, or to the framework of the building. An eccentric or a crank-shaft imparts a horizontal and partly circular movement, no guides being required. The horizontal eccentric working from the motor-shaft makes the sieves wobble to and fro. The centrifugal force, which has alone to be considered, the distances of the sieves from the shaft being symmetrical, is counteracted by a compensating-weight above the eccentric. The machinery is covered in to protect it from dust.

The author describes an apparatus with four sieves, for five classes of mineral, showing the central box, eccentric, balance-weight, and gearing. The sieves are arranged at different levels round the central shaft, with the corresponding delivery- and receiving-troughs, which can be easily removed and emptied. Where the motion is imparted by a vertical crank-shaft, it has a bearing above and a toe-step below. The mineral to be screened passes to the first sieve, falls through into a trough, and is conveyed to the second screen, and so on to all in succession, each screen having smaller meshes than the last. The motion given is smooth and swinging, the vertical shaft makes 140 to 160 revolutions per minute, and the stroke of the sieves is about 4 inches. If thoroughly screened, about eight waggon-loads of coal are delivered by the machine per hour, but this depends on the size of the screen, and number and size of the holes. The weight of the whole apparatus is about 1 ton: the number, angle, and arrangement of the sieves varying according to the size of the coal to be screened. The advantages of the apparatus are its small height and weight; easy access to the sieves, the single shaft being driven from above; facility for withdrawing the coal after screening; less cost of plant and maintenance than in other screens delivering the same quantity; smooth working, and small motive power required.

In another type, the apparatus is circular, and the sieves are arranged spirally in screw-form, set round the vertical shaft. The latter is driven from above, and the frame is suspended in the same way, as already described. Each sieve is longer than the one above, in other words the finer the coal to be screened, the longer the sieves, the length varying from 7½ feet in the first sieve, to 15½ feet in the fourth. In the spiral screens there are no intermediate troughs, the material falling from one sieve to the next, and each sieve is utilized from end to end. The outer

circumference of the sieves rests upon an iron spiral, winding round the central shaft, while the inner circumference starts from the central cylinder. The spiral, which may be placed at any angle, is carried on iron supports, and suspended like the screen. Sometimes a preliminary sifter is added, to prevent the dust from passing through the sieves. The screening may also be reversed, and the smallest coal first withdrawn, the largest last, a simple arrangement which diminishes the height and weight of the apparatus. In the spiral screen, the ground-space varies from 32 to 60 square feet, and the total area of the sieves varies from 64 to 130 square feet. Thus 1 square foot of sieve-surface, only requires about ½ square foot of ground-space. The efficiency depends on the size, number, and area of the holes. The weight is about 1 ton, including the sieves.

In the coal-dressing plant at Fohnsdorf, two Oberegger screens have replaced a Klönne screen, and fill about six and a half waggons of dry coal per hour, but a much larger quantity could be turned out if the mine sent on more coal to the screens, which is not at present possible. The screens are not fixed below, but hang suspended from the roof by wire-ropes or chains, without the least vibration. The four sieves have square holes, measuring respectively 1¼, ¾, ½, and ¼ inch. If the coal be damp, the holes should be smaller and occasionally cleaned, and water assists the screening. The special advantages of the spiral screen are the large ratio of the area of the screens to the ground-space.

A third type may be used, with one sieve for sorting large coal, with two for double sorting, or with several sieves. A horizontal rotating, partly reciprocating, motion is imparted to the screen in front, where the coal is introduced, by a vertical shaft with cranks and balance-weights. The front is supported, and the further end is suspended from the roof, this arrangement giving a circular motion to begin with, and a to-and-fro action afterwards. The path described by the coal is one third larger at the beginning than at the end of the screen. For large coal, the screen is made like a grate, of U-shaped iron bars, and for medium sized coal steel bars are used. The sieves balance each other, their length increases and the angle varies according to the fineness of the coal. There are no guides. Screens of this type, with one, two, and three horizontal screens, have been erected, worked at one end by a crank making 120 to 170 revolutions per minute, according to the size of the apparatus and of the coal. The advantages of this arrangement are that all the parts are balanced; the coal from each sieve can be discharged in front or at the sides, as desired; and the motive power required is small. A double Oberegger screen, with a 4 inches hole upper sieve, and a 2 inches hole lower sieve, is working at Seegraben, in Bohemia, and two single screens have replaced a Briart screen at Fohnsdorf. B. D.

EXPERIMENTS WITH FRUE VANNERS.

Versuche, ausgeführt mit dem Fraser und Chalmer'schen Frue Vanning-ore Concentrator zur Aufbereitung der Pochgänge. By S. RÁKÓCZY. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv., pages* 321, 335, 387, 414, 433, and 443.

In the Transylvania and Upper Hungary districts, a number of frue vanners have been erected during the past decade for concentrating milled pulp, but in many places they did not fulfil the expectations formed with regard to their efficiency and were consequently discarded.

In order to ascertain the causes of the unsatisfactory behaviour of these concentrators in certain cases, and to determine the means of increasing their usefulness, the author was entrusted by the Royal Hungarian Mining Board with the

performance of a series of experiments with a machine supplied by Messrs. Fraser and Chalmers, side by side with parallel tests made with the ordinary percussion-tables used in the district.

From the results of the experiments, which are given in detail in the original paper, the author concludes that the cause of unsatisfactory working of the frue vanner may be traced to the practice of feeding the crushed ore to the machine without previous sizing, a method for which the apparatus is not adapted, and which, therefore, gives poor results. Furthermore, that even with sized pulp, the concentration cannot be satisfactorily effected by means of the frue vanner when the materials are of equal or approximately equal density, viz., in the case of iron and copper pyrites, zinc blende, lead glance, silver ore; and the slime and meal so prepared are unsuitable for recovery in the furnace, since the vanner does not actually concentrate but only separates the denser materials from those specifically lighter. On the other hand, when the barren materials are much less dense than the minerals, the vanner separates them in a very efficient manner, leaving no pyrites in the tailings. Only in the case of lead-ores is it insufficient by itself to concentrate properly, an additional passage of the material over percussion-tables being in that case necessary to secure the best results by concentrating the separated plumbiferous slime.

As regards comparative capacity, the frue vanner in the experiments with coarse-grained pulp from a No. 1 spitzlutte (triangular double troughs) treated 7¾ to 8 tons in twenty-four hours, whereas the percussion-tables could only concentrate 2¾ to 3 tons in the same time, or little more than one-third as much as the vanner. The latter was also found to act well on pyritic silver ores (poor in lead) and on free-gold ores from the Transylvania, and (a specially important consideration for that region) for enriching the pyrites for the manufacture of sulphuric acid and artificial manure.

The subjoined table shows the ratio of efficiency between the two systems in several of the experiments made:—

Origin and Nature of Ore.	Pulp delivered from Spitzlutten.			Quantity treated per Twenty-four Hours.		Excess in favour of the Frue Vanner.	
	1.	1½.	2.	Frue Vanner.	Percussion Table.		
				Tons.	Tons.	Tons.	Per Cent.
Franz Joseph shaft, clayey	No. I.	—	—	3·456	2·880	0·576	20·0
Pacherstolln, free from clay ...	No. I.	—	—	5·600	2·520	3·080	122·2
Do. do. ...	—	No. I.	—	7·750	3·200	4·550	142·2
Franz Joseph shaft, clayey	No. I.	—	—	3·370	2·664	0·706	26·5
Do. do. ...	—	—	No. II.	2·855	1·105	1·750	158·4
Do. do. ...	—	—	No. III.	1·600	1·030	0·570	55·3

The result of this extra capacity of the frue vanner is, that if these machines were employed in place of percussion-tables, a smaller number would suffice to treat the same amount of ore, thus reducing the size of the concentrating-house, and facilitating supervision. It is calculated that the work of No. I. shed of the Franz Joseph shaft at Szent-Antal (where the tests were performed), now requiring twenty percussion-tables and two circular separators for the treatment of 8,000 tons of ore per annum, could be done by eight frue vanners.

Another advantage offered by the frue vanner is, that it delivers, at one washing, slime containing over 70 per cent. of matte, the cost of roasting thereby comparing favourably with that incurred in treating the material from the percussion-tables. C. S.

FRANCOU METHOD OF COAL-WASHING.

Note sur un nouveau Lavoir à Charbon (système Francou). ANON. *Revue Universelle des Mines, etc.*, 1895, *vol. xxxi., page* 166, *and drawings.*

If it be easy to determine beforehand the laws which govern the fall of bodies in water, these laws can only be applied to bodies of regular geometrical form, suspended in a liquid, and moving freely, without being influenced by their surroundings. Such would be the case with pieces of coal, of spherical form, freely suspended in water; but it is by no means the case with the coal subjected to washing, in pieces of all shapes and sizes, not isolated from one another. Hence arises the difficulty of specifying beforehand the manner in which the pieces of coal and shale behave in a washing apparatus. It seemed that the washing of small coal was well performed by strokes of slight amplitude; and, in all felspar washers especially, these short piston strokes, succeeding each other rapidly, constitute veritable vibrations.

In the Francou washer, however, with free-fall of the piston, the pulsations are of considerable amplitude even for washing dust, experience having proved that the separation of shale from coal is better effected under these conditions. On the wash-table is formed a layer of the largest pieces of shale contained in the coal to be washed; and across this layer pass the finest particles of shale, which, traversing the perforated table, fall into a receptacle at the bottom of the washer, whence they are withdrawn by a continuous stream of water, the layer of large pieces of shale acting like the felspar in vibration-washers.

The pulsations are not less than 2½ inches for dust up to ¼ inch, while it may attain 4 inches for small nuts; and this great impulsion of water might appear, at the first glance, likely to derange the work of separation. It is, however, sustained instead of being spasmodic; and, as it is self-regulating according to the state of the wash-bed, it causes no disturbance in the work, the mass of tenuous matter held in suspension by the prolonged but moderate ascending current having every facility for being separated. As the wash-bed is thicker than usual, the two extremes, pure coal and pure shale, are kept farther apart, and are more easily separated.

This thickness in the layer to be washed is also advantageous as regards the cleanness of the coal, because, as the upward travel of the coal is greater, the heaviest pieces have considerable difficulty in reaching the shoot for washed coals, so that they are not so liable to pass over with the latter.

Steam *pistonnage*, with free-fall of the piston, differs from mechanical *pistonnage*, in that the latter, controlled by rigid parts with pre-determined speeds and strokes, always gives the same pulsation during the same space of time, and with the same speed, whatever be the conditions of the wash-bed, while, with free-fall *pistonnage*, the independent piston-stroke is regulated automatically according to the resistance of the wash-bed, whether the variations of resistance be caused by difference of size, various proportions of dust, or accidental conglomeration of the mass.

If, in a washer with a mechanically-driven piston, the wash-bed should become denser through any cause, the piston, with its determined stroke, will force a given volume of water through the wash-table, completely upsetting the action of the apparatus, as would especially be the case if a portion of the table be obstructed

temporarily, which may happen in any washer. If a given volume of water has to pass in a given time across a determined sectional area, and if this area be accidentally reduced—by 20 per cent., for instance—the volume of water passing, during the unit of time, through a free space only 0·80 of the original space will move at a speed greater by 20 per cent., which is sufficient to completely disturb the working of the best-regulated apparatus.

With steam-pistonnage, however, this difficulty does not occur. During the descent of the piston the speed of fall is determined by the weight and by the resistance of the wash-bed. Now the pressure per unit of surface, produced by the weight of the piston and by the column of water, is always the same, the whole difference consisting in the fact that, on the sectional area of the passage diminishing, the volume of water will pass less quickly, the piston will fall more slowly, and there will be less work done; but the action of the apparatus will not be deranged.

The remarkable results obtained with the Francon washer are attributed to the great facility for automatic regulation, coal-dust, in the state of mud, which had been exposed all the winter to rain and frost, having been washed as easily as fresh dust, and the same apparatus having washed, without any change, alternately coal-dust and small nuts, or the two extremes of coal-sizes that are subjected to the operation of washing. J. W. P.

SPECTRUM ANALYSIS OF MINERALS.

Analyse spectrale directe des Minéraux. By VICTOR DESHAYES. *Le Génie Civil*, 1896, *vol. xxix., page* 153.

A new method of direct spectrum analysis has been applied by Mr. Arnaud de Grammont to minerals, just as they occur in nature and without any previous preparation. Starting from the fact that certain well-known minerals, such as galena and pyrites, are sufficiently good conductors of electricity to give a spark between two fragments, he found that most minerals containing the heavy metals, and especially those with metallic lustre, such as the sulphates, the arseniates, and the sulphoantimoniates, possess the same property. He then set about ascertaining whether a spectroscopic examination of the spark passing between two fragments of such a mineral furnishes a direct and rapid method of analysis, qualitative if not quantitative, of the elements entering into the composition of solid compounds, and that without any previous preparation. These investigations, which are still being continued, have already given some interesting results, both with natural minerals and artificial products, such as the industrial alloys; but earthy ores do not lend themselves to spectroscopic examination, as the mineral must be a thoroughly good conductor of electricity or at any rate volatilizable, in which latter case the spectra of lines containing the rays of the elements are also obtained.

The simple method employed consists in passing the electric spark between two similar fragments, not larger than those used in blow-pipe tests, of the mineral to be examined. The fragments are held between two clamps with platinum ends, connected with the poles of an induction-coil actuated by a bichromate of potassium battery; but, instead of using the spark directly from the coil, that of a condenser, formed of several Leyden jars, is employed, as it gives more complete spectra, while possessing several other advantages. Mr. de Grammont's method is simple, rapid, and precise, so far as qualitative analysis is concerned; and in some cases it permits of classing the constituent elements in the order of their importance. J. W. P.

OREDEPOSITS OF SAN LUIS, ARGENTINE REPUBLIC.

Ueber einige Lagerstätten der Argentinischen Provinz San Luis. By DR. J. VALENTIN. *Berg- und Huettenmœnnische Zeitung*, 1896, *vol. lv., pages* 185 *and* 217, *and illustrations.*

The ore-deposits in the chief hill-range of the province of San Luis are separable into two groups, the one genetically related to the Tertiary eruptive rock, and the other to the older crystalline formation, consisting principally of gneiss interspersed with clay, chlorite and mica-schists, etc. The ores of the former class are exclusively venous gold-ores, and occur near the andesite summits of Tomalasta, Porongo, Cerro-del-Valle, and Cerros Largos. In the best-known mines of the Carolina district (with the exception of the Mercedes mine) the ore occurs in veins conformable with the adjacent strata. The Mercedes mines and others of smaller importance, north of Cañada Honda, consist of veins crossing the strata in an east and west direction.

In the Carolina group, the ore lies between layers of gneiss and andesite, extending in a north and south direction for some 3,000 to 7,000 feet, with an easterly dip of 50 to 80 degrees, and consists of a main leader with several parallel veins in the underlay, the total width being 400 to 500 feet. An examination made by the author in the main gallery of the Carolina mine, which cuts the ore-zone perpendicularly, showed that at this point the chief vein was 20 inches thick, and consisted of a thin layer of andesitic tuff and a thicker clayey mass containing lumps of quartz. There were also noticed two quartz-veins of north-and-south strike and easterly dip, and, at a distance of 15 to 20 feet, the so-called western reef composed of a layer of shale and an upper stratum (16 feet thick) of tuff. There is very little doubt of the venous character of these deposits, the ore being younger than the adjacent rock and of about the same age as the andesitic eruptive rock. It probably results from fissures formed in the direction of the dip and strike of the strata, whereas the other similar ore-deposits of the province cut through the strata: the enlargement of the fissures was probably very gradual, as is indicated by the zonal arrangement of the deposits.

Amongst the minerals found in the Mercedes mine are arsenical pyrites and galena. At Cerros Largos, the deposits consist of six parallel veins of quartz running north and south, their maximum length being about 6,500 feet, and the thickness ranging from 4 to 10 feet. The percentage of gold is low, the average quantity not exceeding 154 grains per ton.

The gold found at Cañada Honda occurs in a comparatively limited area in the valley of that name, and is formed of the detritus of the gold-bearing quartz from the vicinity of the andesite formation, the noble metal having been washed down as far as Villa Mercedes, leaving the chief deposits of the denuded material near the original site. The workable deposit has a maximum length of 2,200 feet by 300 feet in width, and is covered to a depth of about 30 feet by a barren layer of black earth, followed by a yellow sandy loam. The gold-bearing deposit (*Llampos*) contains gneiss, crystalline shale, quartzite, and andesite, along with yellow interstitial loam, and has a depth of about 5 feet. A number of depressions, wherein gold has collected, are met with on the surface of the bed-rock, and the latter frequently contains gold to a depth of about 1 foot, probably as a result of mechanical agency rather than segregation. The water-supply for sluicing is very irregular, there being a scarcity in the winter and frequently a superabundance in the summer season. In winter, the chief work is that of washing the deposit exposed by the summer sluicings, and this is effected by three sluices 30 feet long,

12 inches wide, and 8 inches deep, divided into two parts, the lower portion containing the "riffles." Four men and a boy are required for working each sluice, and the average daily win of gold is ½ to ¾ oz. per sluice.

By far the greatest number and variety of ore-deposits occur in the gneiss, crystalline schists, and granite at the western foot of the Sierra de San Francisco (Ayacucho), and in the department of San Martin, but they have been little investigated, and very few particulars of previous workings are obtainable. The most important deposits of gold-ore are found in the Pilon district, to the west of San Francisco, as quartz-veins (strike 30 degrees to north-west and dip south), in grey gneiss. Sometimes at the junction of these veins with the numerous pegmatitic veins the ore is richer than elsewhere, a circumstance considered by Prof. Lallemant to be due to the association of a thin vein of gold-ore with the pegmatitic in some places. Besides pure gold, there also occur iron and copper pyrites, red iron ore, limonite, copper silicate, malachite, etc.

The Rincon ore-deposits lie near to those of Pilon, but the veins do not appear to stand in the same relation to the pegmatite as those in the latter district. Copper-ore predominates, and bornite, copper pyrites, red copper-ore, malachite, spathic and red iron-ore, limonite, and gold are also found.

In the Alto Grande district (San Martin) is the Angelita mine, containing quartz-veins, in gneiss and pegmatite, wherein gold and copper ore are found. The richness varies with the depth, 50 per cent. of copper and 231 grains of gold per ton having been found near the surface, whereas at a depth of about 150 feet the ore contained red ironstone, with 5½ per cent. of copper, and only 123 grains of gold per ton.

Silver lead-ore is found in the gneiss at the Fortuna mine (San Martin), the strike being 15 degrees north-west (magnetic), and the dip nearly or quite perpendicular, the veins having a width of up to 20 inches, and chiefly consisting of poor silver lead-ore; copper compounds and vanadium ore also occur in quantities too small to work. Similar deposits are encountered at La Sala, near the town of San Martin, one sample of galena containing 0·9 per cent. of silver, but the Fortuna mine is the only one possessed of a history, and even that has been abandoned, probably on account of the expense of carting the silver-lead to the station at Villa Mercedes, a distance of about 100 miles. C. S.

II.—BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1895.

By M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32 degs. Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (Plates XXXII. and XXXIII.) recording the meteorological observations.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST DURING 1895, IN THE SEVERAL INSPECTION DISTRICTS.

	Fatal Accidents.			Non-fatal Accidents.	
	No.	Deaths.	Injured.	No.	Injured.
Durham	0	0	0	4	6
Liverpool	1	1	1	3	8
Manchester	1	5	0	2	3
Midland	1	7	0	3	5
Newcastle-upon-Tyne ...	1	1	0	5	7
Scotland, East	2	2	0	29	43
Do. West	2	14	0	47	66
South Wales	7	10	6	29	37
South-Western	2	9	0	2	2
Staffordshire, North ...	0	0	0	4	7
Do. South ...	2	4	3	10	13
Yorkshire	1	2	0	6	9
Totals	20	55	10	144	206

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES DURING 1895.

1895.	Colliery.	District.	Deaths.	No. of Persons Injured.
Feb. 6, 8·45 p.m.	Tirnsbury	South-Western ...	7	0
„ 9, 10·0 a.m.	Morlais Vale ...	South Wales ...	2	1
„ 13, 6·30 „	Glynea	Do.	1	0
„ 25, 1·0 „	Bwllfa Dare	Do.	1	1
Mar. 15, 9·0 p.m.	Malago	South-Western ...	2	0
April 6, 6·30 a.m.	Seafield	Scotland, East ...	1	0
„ 22, 5·30 p.m.	Heddon	Newcastle-upon-Tyne	1	0
„ 26, 1·0 „	Quarter (No. 1) ...	Scotland, West ...	13	0
May 6, 1·5 „	Llantwit Red Ash ...	South Wales ...	1	1
June 18, 3·30 „	Bullfield	Staffordshire, South ...	2	3
July 10, 12·30 a.m.	Crawshays Castle ...	South Wales ...	3	0
„ 16, 10·30 p.m.	Abercrave	Do.	1	3
Aug. 1, 5·0 a.m.	Aberdare Merthyr ...	Do.	1	0
„ 1, 3·30 p.m.	Aldridge	Staffordshire, South	2	0
„ 14, 6·15 a.m.	Pentland	Scotland, East ...	1	0
Sept. 14, 3·30 „	Lea Green	Liverpool	1	1
Oct. 1, 11·30 „	Shakerley	Manchester	5	0
Nov. 5, 10·0 p.m.	Tannochside (No. 2)	Scotland, West ...	1	0
„ 11, 4·0 a.m.	Blackwell A ...	Midland	7	0
„ 21, 8·30 „	Newmarket	Yorkshire	2	0
		Totals ...	55	10

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES DURING 1895.

1895.	Colliery.	Inspection District.	No. of Persons Injured.
Jan. 1, 3·15 a.m.	Pentland	Scotland, East ...	1
„ 10, 7·0 „	Seafield	Do. ...	1
„ 10, 10·0 „	North Skelton ...	Durham	1
„ 12, 7·0 „	Dalmeny	Scotland, East ...	2
„ 16, ...	Aberpergwm	South Wales	1
„ 23, ...	Penygraig	Do.	1
„ 23, ...	Grange Lane	Yorkshire	2
„ 26, 7·0 a.m.	Caprington (No. 40) ...	Scotland, West ...	2
„ 29, ...	Cymmer Glyncorrwg	South Wales	1
„ 31, 11·45 a.m.	Newton (No. 1) ...	Scotland, West ...	1
„ 31, 8·30 p.m.	Orbiston (No. 1) ...	Do. ...	1
„ 31, ...	Llantwit Red Ash ...	South Wales	2
Feb. 5, ...	Fochriw	Do.	2
„ 5, 8·0 a.m.	Monkland (No. 11) ...	Scotland, West ...	2
„ 5, 3·0 p.m.	Neilston (No. 3) ...	Do. ...	1
„ 6, 8·0 a.m.	Pumpherston	Scotland, East ...	2
„ 7, 6·5 „	Eccleston Hall ...	Liverpool	1
„ 11, 5·0 „	Victoria (No. 1) ...	Scotland, West ...	1
„ 14, 1·0 „	New Duffryn	South-Western ...	1
„ 15, 11·0 p.m.	Pentland	Scotland, East ...	1
„ 18, ...	Mynydd Newydd ...	South Wales	1
„ 18, 6·30 a.m.	Coneygre	Staffordshire, South ...	1
„ 18, 6·50 „	Taylor Green	Manchester	1
„ 20, ...	Aberdare Merthyr ...	South Wales	1
„ 20, 4·0 p.m.	Rawyards	Scotland, East ...	2
„ 22, ...	Cymmer Glyncorrwg...	South Wales	1

TABLE III.—*Continued.*

1895.			Colliery.	Inspection District.	No. of Persons Injured.
Feb.	23,	... ...	Cymmer Glyncorrwg...	South Wales	1
,,	24,	7·30 a.m....	Taylor Green	Manchester	2
,,	27,	7·20 ,, ...	Fishley...	Staffordshire, South ...	1
,,	28,	7·30 ,, ...	Dewshill	Scotland, East ...	1
Mar.	4,	10·20 ,, ...	Springbank	Do. ...	1
,,	5,	8·30 ,, ...	Cornsilloch	Do. ...	1
,,	6,	8·30 ,, ...	Pennyvenie (No. 1) ...	Scotland, West ...	1
,,	8,	1·0 p.m....	Caprington (No. 40) ...	Do. ..	1
,,	15,	... ...	Llantwit Red Ash ...	South Wales	1
,,	19,	8·0 a.m....	Dalziel (No. 2) ...	Scotland, West ...	4
,,	24,	11·0 p.m....	Farme (No. 3) ...	Do. ...	1
,,	25,	... ...	Hazlehead	Yorkshire ...	1
,,	26,	... ...	Tannochside (No. 2) ...	Scotland, West ...	1
,,	28,	... ...	Victoria (No. 1) ...	Do. ...	1
April	5,	1·30 p.m....	Point of Ayr	Liverpool ...	2
,,	8,	11·0 a.m....	Foxfield	Staffordshire, North ...	1
,,	8,	7·40 p.m....	Sherdley	Liverpool	5
,,	9,	... ...	Capringstone (No. 7)	Scotland, West ...	1
,,	12,	3·20 p.m....	Rankinston (No. 2) ...	Do. ...	1
,,	18,	... ...	Throckley	Newcastle-upon-Tyne	2
,,	23,	11·0 a.m....	Pollok	Scotland, West ...	1
,,	25,	9·15 ,, ...	Pentland	Do. ...	1
,,	29,	10·15 ,, ...	Ellismuir	Do. ...	4
May	1,	1·0 p.m....	Lingdale	Durham	1
,,	2,	10·0 a.m....	Netherjohnstone(No.1)	Scotland, West ...	1
,,	4,	9·30 ,, ...	Cornsilloch	Scotland, East ...	1
,,	9,	2·0 p.m....	Coppice	Staffordshire, South ...	1
,,	15,	... ...	Cymmer Glyncorrwg	South Wales	1
,,	15,	4·0 p.m....	Aitkenhead	Scotland, West ...	1
,,	15,	10·45 ,, ...	Milnwood (No. 2) ...	Do. ...	1
,,	21,	8·0 a.m....	Boythorpe	Midland	2
,,	22,	3·0 p.m....	Rankinston (No. 2) ...	Scotland, West ...	1
,,	27,	8·0 ,, ...	Skellyton	Scotland, East ...	1
,,	27,	10·45 ,, ...	Sanquhar	Scotland, West ...	2
,,	27,	12·0 ,, ...	Garrochhill	Do. ...	1
June	12,	... ...	Greasbro'	Yorkshire	2
,,	13,	2·0 p.m....	Eastfield	Scotland, West ...	1
,,	18,	9·0 a.m....	Great Wyrley ...	Staffordshire, South ...	1
,,	24,	... ...	Cowpen	Newcastle-upon-Tyne	1
,,	26,	7·30 a.m....	Corby Craigs (No. 4)	Scotland, West ...	1
,,	26,	9·30 ,, ...	Thankerton (No. 6) ...	Do. ...	1
,,	26,	7·30 p.m. ..	Avonhead	Scotland, East ...	1
July	1,	7·0 a.m....	Loudoun (No. 1) ...	Scotland, West ...	1
,,	1,	3·0 p.m....	Tannochside (No. 2.)...	Do. ...	2
,,	2,	... ...	Cyfarthfa, Cwm Pit ...	South Wales	2
,,	3,	1·0 p.m....	Birkrigg	Scotland, East ..	5
,,	8,	6·0 a.m....	Auchenharvie (No. 4.)	Scotland, West ...	1
,,	11,	... ...	Newbridge Rhondda ...	South Wales	1
,,	12,	... ...	Broomhill	Newcastle-upon-Tyne	1
,,	21,	... ...	East Holywell .	Do.	1
,,	27,	10·0 p.m....	Knowle	Staffordshire, South ...	1
Aug.	2,	1·30 a.m....	Addiewell	Scotland, East ...	1
,,	2,	1·30 ,, ...	Quarter	Do. ...	2
,,	7,	... ...	Dirtcar	Yorkshire	1
,,	10,	5·30 p.m....	Wednesbury Oak ...	Staffordshire, South ...	1
,,	11,	... ..	Gilfach	South Wales	1
,,	12,	7·30 a.m...	Clydesdale	Scotland, East ...	1
,,	12,	8·0 p.m....	Lochwood (No. 1) ...	Scotland, West ...	4
,,	19,	7·0 a.m....	Longriggend	Scotland, East ...	2
,,	21,	6·0 ,, ...	Prestongrange ...	Do. ...	1

TABLE III.—*Continued.*

1895.	Colliery.	Inspection District.	No. of Persons Injured.
Aug. 21, 7·15 a.m....	Stanghow	Durham	3
„ 22, 5·30 p.m....	Eastfield (No. 1) ...	Scotland, West ..	1
„ 22, 12·30 „ ...	Netherjohnstone (No. 1)	Do. ...	3
„ 24, 10·30 a.m...	Shelton	Staffordshire, North ...	2
„ 27, 7·0 „ ...	Kinneil	Scotland, East ...	1
„ 30, ...	Gueret's Graigola ...	South Wales	1
Sept. 2, 12 noon ...	Gartshore (No. 9) ...	Scotland, West ...	1
„ 5, ...	Mynydd Newydd ...	South Wales	1
„ 6, ...	Crigglestone	Yorkshire	2
„ 6, 8·0 a.m....	Blairhall	Scotland, East ...	1
„ 9, ...	Gwaun Clawdd ...	South Wales	1
„ 9, 5·0 p.m....	Caprington (No. 40) ...	Scotland, West ...	1
„ 9, 5·30 „ ...	Broomlands (No. 8) ...	Do. ...	4
„ 11, 2·30 „ ...	Granville	Midland	2
„ 19, ...	Cymmer Glyncorrwg...	South Wales	1
„ 23, 7·0 a.m....	Abersychan	South-Western ...	1
„ 24, ...	Rock Castle	South Wales... ...	1
„ 26, ...	Scholes	Yorkshire	1
„ 27, 12 noon ...	Thankerton (No. 6) ...	Scotland, West ...	1
„ 30, 5·0 a.m....	Daldowie	Do. ...	1
„ 30, 9·0 „ ..	Clyde	Scotland, East ...	1
Oct. 2, ...	Glyn	South Wales	4
„ 2, ...	Ystradowen	Do.	1
„ 7, 7·45 a.m....	Polbeth	Scotland, East ...	3
„ 8, ...	Glyn	South Wales	1
„ 8, 3·0 a.m...	Westburn (No. 2) ...	Scotland, West ...	1
„ 9, 7·0 „ ...	Newton (No. 1) ...	Do. ...	1
„ 11, ...	Llantwit Red Ash ...	South Wales	1
„ 14, ...	Newbridge Rhondda ...	Do.	1
„ 14, 5·30 a.m....	Pennyvenie (No. 3) ...	Scotland, West ..	1
„ 15, 3·15 p.m....	Norton Cannock ...	Staffordshire, South ...	3
„ 16, 6·30 a.m....	Exhall	Midland	1
„ 17, ...	Rock Castle	South Wales	2
„ 22, 3·40 a.m....	Gartness	Scotland, East ...	1
„ 23, 6·0 „ ...	Rosehall (No. 13) ...	Scotland, West ...	1
„ 23, 12·45 p.m....	Lumpsey	Durham ...	1
„ 24, 8·0 a.m....	Dunmore	Scotland, West ...	1
„ 25, 8·15 p.m....	Gilbertfield (No. 1) ...	Do. ...	1
„ 31, 5·0 „ ...	Madeley Wood ...	Staffordshire, North ...	2
Nov. 1, ...	Llanerch	South Wales	1
„ 1, ...	Llantwit Red Ash ...	Do.	1
„ 6, 2·15 a.m....	Dalziel (No. 2) ...	Scotland, West ...	2
„ 6, 7·0 „ ...	Monkland	Scotland, East ...	1
„ 6, 9·0 „ ..	Birkrigg	Do. ...	2
„ 11, 9·15 „ ...	Shut End	Staffordshire, South ...	1
„ 25, ...	Rock Castle	South Wales	2
„ 26, 10·30 a.m....	Ubberley Hall ...	Staffordshire, North ...	2
Dec. 12, 12 noon ...	Aitkenhead	Scotland, West ...	1
„ 12, 12 „ ...	Longriggend	Scotland, East ...	1
„ 13, 11·0 a.m....	East Plean	Scotland, West ...	1
„ 16, ...	Abercrave	South Wales	1
„ 17, 9·45 p.m....	Pelsall	Staffordshire, South ...	1
„ 21, 6·15 a.m....	Birkrigg	Scotland, East ...	3
„ 21, 12 noon ...	Woodhall	Scotland, West ...	1
„ 23, 10·0 p.m....	Blakeley Wood ...	Staffordshire, South ...	2
„ 24, 4·30 a.m....	Haughhead	Scotland, West ...	1
„ 27, 11·30 p.m....	Earnock	Scotland, East ...	1
„ 30, ...	Ravensworth	Newcastle-upon-Tyne	2
		Total	206

TABLE IV.—BAROMETER, THERMOMETER, ETC., READINGS, 1895.

JANUARY, 1895.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	29·810	29·909	29·988	30·073	35·9	29·0	NNW	1	29·976	30·042	29·973	29·784	39·5	30·7	W
2	29·994	29·846	29·765	29·593	41·7	29·6	WNW	2	29·739	29·640	29·538	29·486	41·4	31·9	SW
3	29·457	29·480	29·535	29·636	36·2	32·6	N	3	29·462	29·603	29·798	29·961	36·9	28·1	NNW
4	29·746	29·894	29·918	29·954	37·8	34·7	N	4	30·078	30·180	30·187	30·209	35·2	26·3	NW
5	29·953	29·961	29·908	29·925	37·6	33·1	N	5	30·139	30·036	29·907	29·903	33·9	24·2	NNE
6	29·876	29·818	29·677	29·582	33·1	28·6	N	6	29·809	29·722	29·706	29·700	37·3	27·3	NW
7	29·563	29·675	29·730	29·782	33·0	29·3	N	7	29·672	29·911	29·973	30·014	35·4	27·4	N
8	29·776	29·802	29·808	29·832	37·3	31·4	N	8	29·983	29·993	29·952	29·940	30·9	22·1	N
9	29·823	29·868	29·874	29·900	34·6	29·8	N	9	29·915	29·922	29·896	29·901	23·9	15·1	WNW
10	29·912	29·915	29·859	29·846	32·1	24·7	N	10	29·886	29·869	29·814	29·807	26·0	15·0	E
11	29·830	29·856	29·809	29·764	29·1	24·4	NW	11	29·779	29·766	29·667	29·627	32·7	22·3	E
12	29·661	29·592	29·433	29·246	32·9	24·8	ESE	12	29·548	29·468	29·384	29·295	33·4	22·9	E
13	29·004	29·001	29·055	29·030	41·6	28·3	S	13	29·164	29·044	28·953	28·984	36·2	32·5	E
14	28·951	28·925	28·990	29·057	42·5	38·2	ESE	14	28·939	28·937	28·962	28·956	38·8	33·0	E
15	29·056	29·075	29·037	29·022	42·6	39·0	ESE	15	29·017	29·062	29·055	29·037	37·9	35·7	NE
16	28·997	29·021	29·045	29·016	45·0	38·8	S	16	28·998	28·975	28·941	28·943	38·6	35·0	ENE
17	28·941	29·084	29·229	29·431	44·2	37·3	SW	17	28·939	28·978	29·002	29·116	37·5	33·1	W
18	29·603	29·701	29·739	29·816	44·5	32·8	SSW	18	29·251	29·376	29·502	29·641	40·2	33·8	WSW
19	29·794	29·773	29·655	29·499	45·6	32·3	SSE	19	29·694	29·756	29·718	29·697	38·0	29·3	E
20	29·444	29·468	29·449	29·461	51·8	40·6	SSW	20	29·672	29·711	29·734	29·801	38·1	32·1	ENE
21	29·464	29·589	29·750	29·932	42·6	31·8	NNE	21	29·836	29·980	30·038	30·010	34·8	29·3	NNE
22	29·955	29·882	29·788	29·815	34·8	27·4	SW	22	29·743	29·783	29·773	29·706	41·0	31·6	W
23	29·643	29·553	29·659	29·814	40·5	27·8	N	23	29·531	29·745	29·771	29·629	41·6	31·1	N
24	29·698	29·345	29·092	29·168	42·5	28·9	SW	24	29·146	28·956	29·078	29·352	40·4	33·3	W
25	29·343	29·525	29·549	29·621	38·3	26·7	NW	25	29·498	29·589	29·580	29·648	37·7	27·4	NW
26	29·648	29·722	29·719	29·721	33·9	24·6	NW	26	29·686	29·671	29·595	29·488	33·0	26·9	W
27	29·734	29·799	29·779	29·819	31·2	22·5	NNW	27	29·353	29·646	29·785	29·911	34·5	27·1	NW
28	29·857	29·983	30·095	30·222	30·8	22·1	NW	28	29·993	30·099	30·145	30·142	29·5	20·4	W
29	30·242	30·233	30·193	30·270	31·5	20·6	W	29	30·000	30·064	30·220	30·421	34·4	26·9	NE
30	30·344	30·426	30·429	30·411	33·1	22·7	ENE	30	30·542	30·681	30·679	30·688	32·1	22·3	E
31	30·304	30·136	30·043	30·031	33·9	24·3	N	31	30·632	30·534	30·350	30·283	33·1	18·6	NNE

FEBRUARY, 1895.

1	30·018	30·010	29·993	29·974	31·0	24·6	ENE	1	30·244	30·245	30·227	30·219	35·9	28·9	ENE
2	29·924	29·905	29·906	29·987	34·3	23·2	NE	2	30·105	30·011	30·019	30·099	36·1	33·0	NE
3	29·973	29·989	30·004	30·085	33·5	22·	ENE	3	30·114	30·162	30·180	30·258	37·6	33·6	NE
4	30·118	30·160	30·139	30·142	34·2	27·9	NE	4	30·247	30·260	30·241	30·300	38·0	31·7	ENE
5	30·104	30·066	29·954	29·930	29·6	19·7	ENE	5	30·247	30·164	30·016	29·909	36·6	31·1	NE
6	29·849	29·818	29·761	29·794	25·1	14·5	NE	6	29·769	29·656	29·639	29·719	33·0	21·4	NW
7	29·822	29·856	29·871	29·913	25·1	10·8	SE	7	29·719	29·766	29·808	29·885	24·0	20·3	E
8	29·914	29·928	29·924	30·005	27·8	11·6	NE	8	29·915	29·962	29·965	30·023	22·9	10·9	E
9	30·072	30·132	30·084	30·021	23·1	11·7	NNE	9	30·043	30·048	29·998	29·966	22·3	10·3	W
10	29·918	29·859	29·739	29·632	30·2	18·7	ESE	10	29·906	29·868	29·801	29·794	26·2	6·6	E
11	29·558	29·617	29·668	29·767	31·1	20·7	ENE	11	29·778	29·792	29·765	29·816	28·7	11·5	N
12	29·823	29·908	29·965	30·065	35·9	17·2	WSW	12	29·851	29·909	29·954	30·019	30·5	11·2	NNW
13	30·115	30·175	30·194	30·243	30·8	17·3	NNW	13	30·033	30·060	30·083	30·123	33·6	17·2	SE
14	30·253	30·293	30·274	30·272	29·0	20·1	E	14	30·165	30·247	30·269	30·360	30·3	22·6	ESE
15	30·227	30·256	30·218	30·272	32·1	26·1	NE	15	30·379	30·432	30·433	30·517	34·1	22·2	E
16	30·304	30·391	30·426	30·463	34·2	27·9	ENE	16	30·543	30·583	30·590	30·606	38·3	27·0	ENE
17	30·473	30·467	30·421	30·422	31·1	19·5	ENE	17	30·569	30·540	30·484	30·447	36·6	27·0	NE
18	30·382	30·335	30·263	30·228	36·9	19·2	NNE	18	30·392	30·357	30·316	30·301	36·0	25·2	W
19	30·216	30·254	30·246	30·280	38·3	28·	NNE	19	30·322	30·326	30·304	30·332	31·1	19·9	NNE
20	30·298	30·319	30·294	30·318	40·1	25·1	NNE	20	30·329	30·357	30·324	30·357	35·0	23·2	NW
21	30·301	30·308	30·280	30·265	43·2	34·7	NNE	21	30·337	30·332	30·303	30·325	44·2	27·2	W
22	30·266	30·298	30·308	30·343	40·3	35·8	NNE	22	30·323	30·337	30·321	30·338	40·9	27·7	WSW
23	30·333	30·302	30·177	30·129	44·8	33·3	N	23	30·280	30·202	30·095	30·020	45·4	35·7	WSW
24	29·999	29·877	29·707	29·702	44·0	34·2	WSW	24	29·762	29·785	29·907	29·956	42·1	36·7	NE
25	29·725	29·838	29·891	29·975	36·1	30·8	NE	25	29·983	30·053	30·041	30·027	40·8	31·1	N
26	29·939	29·897	29·700	29·671	40·4	28·4	W	26	29·866	29·696	29·677	29·775	47·0	29·5	W
27	29·725	29·763	29·799	29·870	40·1	31·8	N	27	29·780	29·825	29·843	29·865	41·1	33·3	WNW
28	29·941	30·022	30·005	29·984	44·9	31·4	WNW	28	29·838	29·777	29·705	29·522	45·0	33·9	W

MARCH, 1895.

KEW.								GLASGOW.							
	Barometer.				Temperature.				Barometer.				Temperature.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	29·862	29·774	29·682	29·709	47·9	35·3	WSW	1	29·481	29·489	29·560	29·686	43·8	33·5	W
2	29·715	29·769	29·716	29·681	37·8	30·9	N	2	29·725	29·727	29·644	29·627	37·9	28·9	NW
3	29·605	29·587	29·588	29·666	38·0	26·1	NNW	3	29·538	29·674	29·668	29·664	35·1	28·8	NNW
4	29·680	29·773	29·813	29·869	39·8	26·2	N	4	29·862	29·942	29·930	29·931	40·8	30·6	NNW
5	29·873	29·910	29·894	29·903	41·6	31·8	N	5	29·867	29·827	29·738	29·677	42·9	32·9	W
6	29·856	29·842	29·806	29·815	43·1	34·6	SSW	6	29·570	29·517	29·435	29·524	42·9	37·0	S
7	29·787	29·817	29·807	29·834	47·5	35·5	WSW	7	29·602	29·638	29·593	29·587	46·5	32·2	W
8	29·782	29·723	29·646	29·635	48·1	34·1	S	8	29·524	29·507	29·447	29·466	41·7	35·8	SE
9	29·609	29·561	29·434	29·388	43·2	38·3	ESE	9	29·472	29·511	29·457	29·396	45·1	36·6	E
10	29·380	29·454	29·459	29·514	50·2	36·5	SSW	10	29·355	29·343	29·299	29·362	39·2	35·6	NE
11	29·530	29·563	29·548	29·604	53·7	30·6	SSW	11	29·378	29·432	29·474	29·558	38·7	33·7	ESE
12	29·624	29·644	29·645	29·749	50·2	34·3	ENE	12	29·608	29·701	29·763	29·852	38·6	32·9	E
13	29·825	29·969	30·060	30·184	44·5	33·2	NNE	13	29·910	29·985	29·984	29·993	44·6	32·2	NE
14	30·242	30·312	30·274	30·335	54·0	28·5	W	14	29·970	30·039	30·020	30·021	47·5	39·0	SW
15	30·355	30·377	30·354	30·379	51·8	40·2	W	15	30·056	30·092	30·100	30·131	48·7	44·1	SW
16	30·347	30·350	30·295	30·306	55·7	40·2	W	16	30·137	30·183	30·180	30·184	51·8	42·8	SW
17	30·285	30·274	30·185	30·195	54·5	38·2	W	17	30·154	30·170	30·146	30·166	52·1	39·0	SW
18	30·184	30·197	30·085	30·049	58·2	32·7	N	18	30·133	30·043	29·875	29·832	48·7	35·2	SW
19	30·002	30·026	29·947	29·852	53·2	38·1	W	19	29·836	29·807	29·615	29·631	48·5	39·9	SW
20	29·779	29·829	29·889	29·950	54·1	45·7	NNW	20	29·681	29·771	29·800	29·836	48·6	39·9	W
21	29·930	29·935	29·859	29·910	61·2	45·1	WSW	21	29·746	29·735	29·747	29·719	53·6	39·3	WNW
22	29·902	29·946	29·912	29·959	62·0	41·9	WNW	22	29·725	29·825	29·819	29·811	51·5	43·4	W
23	29·959	29·928	29·829	29·680	54·1	38·1	SW	23	29·684	29·502	29·307	29·062	50·2	45·0	SSW
24	29·497	29·301	29·344	29·496	57·1	43·7	SW	24	28·821	28·865	28·913	29·033	51·5	37·3	W
25	29·416	29·280	29·098	29·049	53·1	40·6	SW	25	28·979	28·848	28·734	28·803	45·7	37·5	SW
26	29·017	29·173	29·416	29·527	51·8	40·5	NNW	26	28·901	29·095	29·215	29·257	45·9	33·2	WNW
27	29·383	29·094	29·025	28·941	53·8	39·8	SW	27	29·176	29·103	28·983	28·865	44·9	36·2	E
28	28·935	28·854	28·909	29·002	49·0	41·8	SW	28	28·682	28·636	28·682	28·838	39·7	34·6	NE
29	28·995	29·063	29·154	29·256	47·1	40·1	W	29	28·913	29·031	29·080	29·174	45·1	37·1	NW
30	29·299	29·330	29·338	29·398	47·3	36·6	WNW	30	29·262	29·397	29·466	29·510	46·0	38·1	N
31	29·420	29·509	29·536	29·591	49·9	35·8	NW	31	29·476	29·491	29·480	29·542	45·5	37·6	N

APRIL, 1895.

1	29·598	29·658	29·701	29·827	49·2	29·7	WNW	1	29·624	29·768	29·888	30·052	44·8	37·1	NE
2	29·829	29·858	29·863	29·936	46·1	39·8	NE	2	30·058	30·076	30·000	29·965	47·7	38·6	N
3	29·933	29·944	29·897	29·913	46·7	38·5	N	3	29·903	29·878	29·909	30·018	50·9	35·3	NW
4	29·978	30·104	30·172	30·252	44·4	37·7	ENE	4	30·072	30·124	30·123	30·155	43·1	31·9	NW
5	30·248	30·216	30·063	29·963	49·1	36·2	W	5	30·080	29·971	29·779	29·551	46·9	32·7	SW
6	29·781	29·581	29·376	29·310	47·9	39·1	SW	6	29·203	29·048	29·007	29·166	49·8	41·4	WSW
7	29·281	29·365	29·544	29·685	49·0	37·2	NNE	7	29·280	29·395	29·478	29·562	45·4	30·6	WNW
8	29·723	29·802	29·790	29·818	56·3	39·7	W	8	29·588	29·604	29·454	29·286	49·7	31·1	S
9	29·825	29·917	29·917	29·975	62·2	47·7	WSW	9	29·424	29·590	29·659	29·619	52·7	44·2	SW
10	29·989	30·009	30·036	30·144	60·6	45·7	SW	10	29·541	29·589	29·781	29·911	52·1	45·1	WSW
11	30·213	30·286	30·267	30·328	58·1	39·2	WNW	11	29·983	30·106	30·212	30·334	51·8	41·3	WNW
12	30·337	30·348	30·248	30·240	53·9	38·0	NE	12	30·335	30·301	30·193	30·165	48·6	35·8	W
13	30·211	30·227	30·193	30·244	52·0	35·1	E	13	30·179	30·269	30·265	30·322	51·4	39·0	E
14	30·257	30·269	30·213	30·211	51·7	36·8	E	14	30·327	30·335	30·357	30·273	57·1	33·6	E
15	30·142	30·104	29·981	29·991	51·2	31·5	NE	15	30·250	30·235	30·142	30·149	53·8	35·4	E
16	29·924	29·899	29·798	29·782	56·3	38·6	ENE	16	30·080	30·015	29·909	29·905	53·4	35·0	E
17	29·731	29·697	29·602	29·594	63·6	43·6	NE	17	29·858	29·796	29·691	29·684	48·6	38·8	NE
18	29·559	29·600	29·614	29·682	60·3	47·0	WSW	18	29·623	29·596	29·547	29·565	53·9	39·0	E
19	29·723	29·802	29·822	29·916	61·9	44·8	WSW	19	29·559	29·628	29·675	29·769	56·7	44·9	W
20	29·954	30·001	29·967	29·962	64·1	48·6	SSW	20	29·792	29·827	29·788	29·690	57·1	46·5	S
21	29·893	29·905	29·882	29·917	60·7	51·2	SSW	21	29·583	29·595	29·592	29·655	56·9	49·5	SSW
22	29·919	29·926	29·793	29·652	59·2	50·7	SSW	22	29·663	29·673	29·545	29·359	57·3	44·9	S
23	29·563	29·612	29·618	29·726	62·2	44·6	W	23	29·256	29·362	29·413	29·462	57·2	49·3	SW
24	29·711	29·666	29·608	29·635	62·6	43·3	S	24	29·477	29·485	29·428	29·359	57·2	47·1	SSW
25	29·553	29·592	29·588	29·422	57·1	44·2	S	25	29·432	29·489	29·438	29·391	54·2	45·1	WNW
26	29·365	29·424	29·436	29·479	54·2	47·4	SW	26	29·311	29·332	29·377	29·467	49·1	44·8	NNW
27	29·484	29·565	29·640	29·771	52·0	46·4	W	27	29·552	29·672	29·779	29·895	56·0	45·7	NNE
28	29·878	30·019	30·075	30·133	55·1	49·8	NNE	28	29·957	30·009	30·001	30·016	59·1	46·9	SW
29	30·131	30·150	30·116	30·167	63·8	37·4	WNW	29	29·987	29·980	29·932	29·932	53·9	42·6	S
30	30·185	30·217	30·193	30·201	61·4	44·1	WSW	30	29·996	30·056	29·984	29·864	56·1	41·9	SW

SEPTEMBER, 1895.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	30·110	30·098	29·999	29·970	72·3	44·9	S	1	29·872	29·850	29·846	29·860	65·2	54·6	SW
2	29·891	29·876	29·918	30·005	72·7	55·4	SSW	2	29·796	29·772	29·752	29·778	70·5	52·1	S
3	30·012	30·022	29·873	29·866	75·7	52·2	W	3	29·749	29·824	29·836	29·865	63·3	53·5	SW
4	29·984	30·096	30·077	30·113	73·0	55·0	WSW	4	29·868	29·873	29·826	29·853	60·1	51·5	SSW
5	30·075	30·062	30·003	30·029	71·3	50·2	SSW	5	29·852	29·853	29·842	29·911	61·1	51·1	SW
6	30·034	30·098	30·047	30·036	74·0	60·9	SW	6	29·962	30·032	30·001	29·942	64·0	43·7	SW
7	29·883	29·933	29·992	30·087	76·3	61·0	W	7	29·817	29·812	29·878	29·995	62·7	53·7	WSW
8	30·144	30·189	30·156	30·173	73·3	56·7	ENE	8	30·035	30·090	30·073	30·069	61·8	52·3	SW
9	30·134	30·108	29·990	29·923	78·7	55·3	ESE	9	30·006	29·947	29·800	29·714	74·7	50·1	S
10	29·851	29·875	29·791	29·759	71·8	56·8	SW	10	29·626	29·560	29·441	29·281	65·2	56·0	SSW
11	29·743	29·776	29·789	29·894	66·6	54·1	WSW	11	29·194	29·247	29·408	29·603	59·7	53·2	W
12	29·951	30·025	30·057	30·122	62·6	50·9	W	12	29·711	29·800	29·923	30·041	58·1	49·7	WNW
13	30·151	30·211	30·201	30·219	62·5	47·7	NNW	13	30·098	30·159	30·169	30·173	59·9	47·0	WNW
14	30·211	30·236	30·207	30·257	65·0	42·7	NNW	14	30·159	30·170	30·185	30·229	59·4	53·4	WSW
15	30·267	30·310	30·269	30·289	66·8	45·1	WNW	15	30·236	30·241	30·216	30·211	59·6	52·0	WSW
16	30·290	30·301	30·218	30·213	68·1	46·0	WSW	16	30·150	30·142	30·065	30·011	58·7	51·2	WSW
17	30·173	30·180	30·060	30·070	69·7	48·7	WSW	17	29·950	29·888	29·795	29·824	58·4	56·0	SW
18	30·064	30·071	29·979	30·041	72·9	53·5	WSW	18	29·766	29·678	29·711	29·928	62·8	50·6	WSW
19	30·043	30·117	30·156	30·242	60·0	47·8	WSW	19	29·987	30·065	30·136	30·259	60·3	47·0	W
20	30·297	30·373	30·329	30·361	63·7	41·0	E	20	30·278	30·332	30·295	30·289	57·7	42·3	NW
21	30·343	30·381	30·335	30·362	62·9	40·8	E	21	30·255	30·260	30·229	30·266	62·2	42·0	SW
22	30·335	30·316	30·248	30·247	68·2	38·6	E	22	30·252	30·241	30·175	30·169	62·2	47·0	SW
23	30·224	30·245	30·198	30·216	75·3	43·4	E	23	30·136	30·140	30·117	30·125	64·3	39·2	W
24	30·191	30·191	30·130	30·166	80·2	53·7	NE	24	30·084	30·063	30·060	30·093	64·1	51·2	W
25	30·151	30·195	30·191	30·254	76·9	57·6	SSW	25	30·088	30·078	30·082	30·109	70·4	51·7	N
26	30·251	30·266	30·215	30·228	79·4	55·4	E	26	30·107	30·167	30·148	30·175	69·3	58·5	W
27	30·194	30·200	30·157	30·207	78·6	60·0	E	27	30·162	30·179	30·136	30·179	72·5	55·1	E
28	30·195	30·220	30·180	30·213	75·7	56·2	E	28	30·183	30·228	30·180	30·237	70·5	53·8	N
29	30·194	30·185	30·120	30·121	73·3	50·4	ENE	29	30·190	30·200	30·132	30·128	62·1	54·4	N
30	30·063	30·034	29·900	29·871	74·9	54·1	E	30	30·080	30·026	29·884	29·816	69·1	47·3	W

OCTOBER, 1895.

1	29·787	29·761	29·668	29·599	70·9	53·0	SSW	1	29·731	29·628	29·452	29·314	66·6	49·0	ENE
2	29·319	29·473	29·542	29·625	62·4	41·6	W	2	29·126	29·070	29·211	29·332	59·5	40·2	NW
3	29·634	29·365	29·318	29·391	63·9	39·9	WSW	3	29·247	29·015	28·893	28·990	43·6	39·5	ESE
4	29·322	29·413	29·571	29·790	59·0	41·0	WNW	4	29·068	29·291	29·454	29·484	48·4	38·0	WNW
5	29·814	29·796	29·725	29·577	58·8	37·8	SW	5	29·380	29·392	29·407	29·408	52·4	43·2	WSW
6	29·547	29·581	29·564	29·616	59·1	49·9	SSW	6	29·417	29·455	29·456	29·423	52·3	42·3	W
7	29·672	29·743	29·693	29·612	56·9	44·8	W	7	29·415	29·451	29·431	29·388	51·1	41·6	WSW
8	29·433	29·328	29·204	29·087	56·5	49·9	ESE	8	29·355	29·404	29·389	29·408	52·8	43·1	N
9	29·027	29·099	29·272	29·428	54·3	49·2	NNW	9	29·334	29·290	29·301	29·420	51·1	44·6	N
10	29·511	29·629	29·788	29·946	52·2	40·5	NNW	10	29·538	29·690	29·777	29·809	52·1	41·2	NW
11	30·013	30·076	30·110	30·134	56·1	37·6	WNW	11	29·885	29·961	29·873	29·753	51·6	43·1	SW
12	30·094	30·124	30·143	30·201	58·7	47·5	W	12	29·698	29·773	29·870	29·974	57·0	51·7	SW
13	30·194	30·200	30·145	30·130	55·5	45·9	WNW	13	29·957	29·942	29·890	29·874	53·1	50·5	SW
14	30·065	30·033	29·958	29·976	59·4	47·7	SW	14	29·826	29·834	29·899	29·979	51·8	45·8	NE
15	29·965	29·957	29·880	29·893	60·6	43·0	W	15	30·078	29·996	29·992	30·047	47·3	42·0	E
16	29·905	30·136	30·240	30·371	57·3	38·9	NNE	16	30·128	30·249	30·333	30·425	49·1	36·8	N
17	30·415	30·473	30·460	30·507	52·2	34·0	NE	17	30·464	30·508	30·472	30·475	48·9	31·8	NE
18	30·494	30·523	30·455	30·451	53·6	31·6	NE	18	30·445	30·447	30·389	30·378	50·9	32·9	SW
19	30·398	30·384	30·286	30·274	50·9	35·4	ENE	19	30·336	30·320	30·238	30·204	51·1	32·9	NW
20	30·224	30·238	30·191	30·183	51·8	37·7	ENE	20	30·170	30·252	30·216	30·160	48·0	41·8	E
21	30·114	30·048	29·925	29·847	50·5	35·1	WSW	21	30·053	30·048	30·022	30·044	42·7	35·5	NE
22	29·738	29·691	29·618	29·610	43·5	39·8	NNE	22	30·014	29·988	29·894	29·848	42·9	34·8	N
23	29·568	29·576	29·541	29·533	43·7	34·2	NNE	23	29·750	29·719	29·616	29·515	43·0	30·1	N
24	29·515	29·516	29·474	29·463	45·4	28·6	W	24	29·389	29·384	29·352	29·366	43·3	31·8	NW
25	29·493	29·517	29·494	29·504	46·0	29·7	WNW	25	29·374	29·382	29·375	29·468	42·5	32·0	NW
26	29·516	29·545	29·553	29·650	38·9	25·3	WNW	26	29·574	29·679	29·636	29·623	43·3	31·5	NNW
27	29·695	29·718	29·717	29·739	43·7	28·1	WNW	27	29·626	29·682	29·666	29·685	43·1	31·3	W
28	29·732	29·758	29·708	29·715	44·0	25·1	SW	28	29·635	29·618	29·644	29·740	40·5	28·5	W
29	29·722	29·806	29·861	29·972	40·1	32·3	NNW	29	29·801	29·925	29·988	30·044	43·9	33·4	N
30	30·060	30·134	30·058	30·001	45·2	30·6	W	30	29·997	29·820	29·714	29·663	47·9	32·8	SW
31	29·866	29·880	29·967	30·121	50·1	41·4	SSW	31	29·750	29·963	30·106	30·261	45·9	37·8	NE

NOVEMBER, 1895.

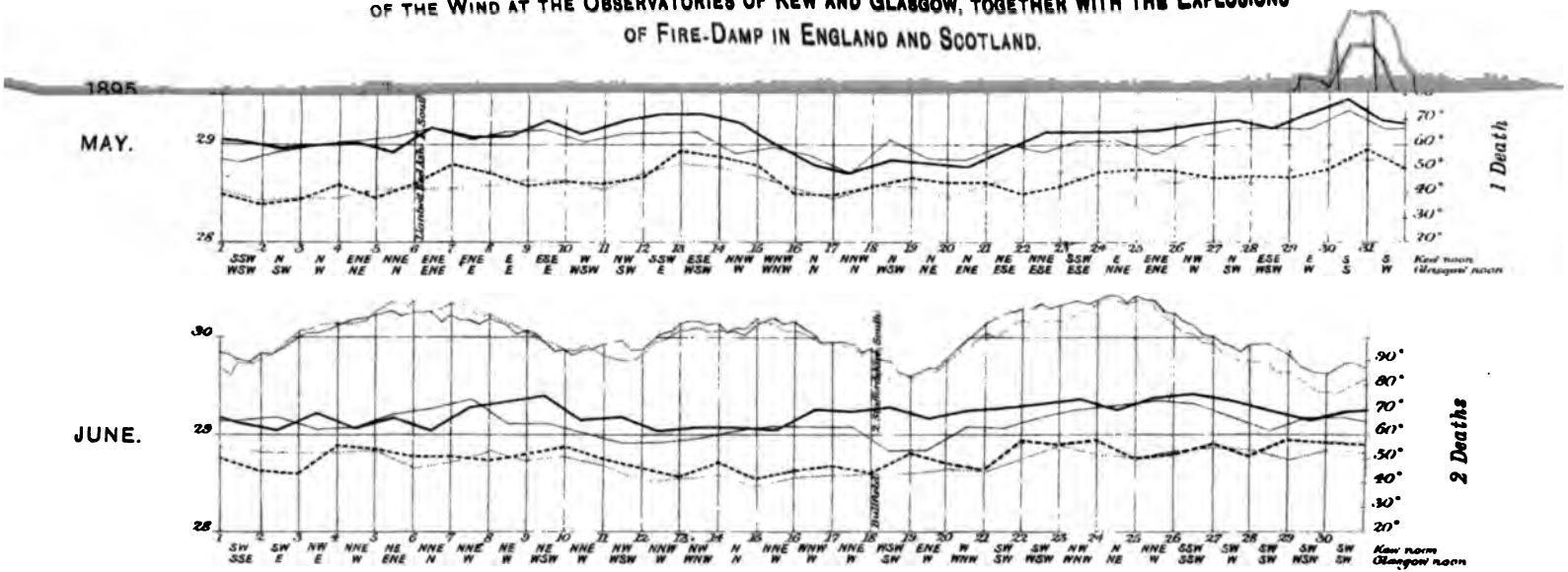
KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	30·246	30·408	30·420	30·435	54·3	38·3	SE	1	30·363	30·471	30·459	30·477	43·2	30·2	NE
2	30·357	30·247	30·075	30·049	49·5	33·0	ESE	2	30·406	30·341	30·185	30·118	43·8	35·0	NE
3	29·991	29·945	29·838	29·778	49·6	32·1	SSE	3	30·005	29·965	29·852	29·808	40·7	32·0	E
4	29·753	29·729	29·567	29·574	50·9	44·5	SE	4	29·750	29·717	29·635	29·561	42·1	39·2	ENE
5	29·549	29·504	29·501	29·251	58·0	40·9	SW	5	29·476	29·399	29·146	28·806	49·8	40·1	ESE
6	29·440	29·554	29·645	29·757	59·4	52·6	WSW	6	28·728	28·872	29·027	29·196	50·9	46·4	SW
7	29·825	29·853	29·833	29·883	59·1	50 8	SW	7	29·395	29·563	29·600	29·672	52·1	45·6	SW
8	29·944	29·944	29·840	29·745	56·2	51·1	SW	8	29·706	29·757	29·753	29·711	50·6	44·8	SW
9	29·630	29·703	29·820	29·860	56·5	45·6	NW	9	29·594	29·555	29·565	29·583	47·9	40·1	W
10	29·798	29·686	29·518	29·294	55·9	44·9	SSW	10	29·394	29·148	29·019	28·500	53·0	37·2	SSW
11	29·184	29·292	29·306	29·265	53·9	45·8	WSW	11	28·513	28·874	28·950	28·873	54·4	40·8	SW
12	29·266	29·201	29·135	29·217	50·3	42·0	SSW	12	28·806	28·762	28·821	28·842	44·5	37·4	SW
13	29·354	29·594	29·772	29·862	53·9	42·7	W	13	29·034	29·249	29·390	29·427	48·4	39·8	W
14	29·840	29·804	29·792	29·996	55·2	43·2	SW	14	29·348	29·334	29·387	29·573	46·4	39·0	WSW
15	30·038	29·986	29·711	29·695	58·6	37·1	S	15	29·694	29·560	29·140	29·244	54·7	39·1	S
16	29·710	29·675	29·606	29·965	61·6	46·2	SSW	16	29·357	29·210	29·188	29·476	48·7	38·5	SW
17	30·047	30·094	30·143	30·267	54·3	38·2	WSW	17	29·567	29·777	29·895	30·020	45·6	38·0	WSW
18	30·334	30·380	30·336	30·312	48·7	29·9	WSW	18	30·091	30·172	30·147	30·166	46·6	37·2	SW
19	30·230	30·175	30·080	30·012	47·7	38·0	ESE	19	30·126	30·108	30·008	29·939	43·2	36·8	ESE
20	29·920	29·897	29·881	29·929	51·6	46·9	SE	20	29·846	29·821	29·768	29·827	50·4	40·2	ENE
21	29·932	30·000	30·028	30·101	51·8	46·6	ESE	21	29·859	29·916	29·881	29·895	50·8	47·1	ENE
22	30·142	30·178	30·095	30·003	53·0	42·8	WNW	22	29·959	30·071	29·952	29·941	51·5	41·9	W
23	29·780	29·745	29·802	30·077	46·0	37·4	N	23	30·025	30·151	30·272	30·368	42·7	37·0	NE
24	30·183	30·231	30·174	30·187	43·9	37·8	NE	24	30·436	30·494	30·500	30·510	42·4	36·1	ESE
25	30·205	30·199	30·169	30·169	44·1	41·9	NE	25	30·494	30·497	30·432	30·395	42·9	36·6	E
26	30·130	30·138	30·065	30·053	42·0	35·6	ESE	26	30·326	30·258	30·145	30·082	44·5	41·0	E
27	29·982	29·969	29·896	29·899	47·0	35·7	E	27	29·981	29·958	29·921	29·904	43·9	40·5	E
28	29·849	29·829	29·757	29·768	50·4	37·9	E	28	29·866	29·850	29·779	29·730	45·2	41·0	S
29	29·702	29·661	29·577	29·546	52·1	49·0	SE	29	29·645	29·657	29·640	29·653	47·3	43·8	ENE
30	29·549	29·631	29·738	29·905	51·4	42·7	W	30	29·622	29·644	29·65 2	29·707	46·4	42·1	W

DECEMBER, 1895.

1	29·957	30·028	29·997	30·062	46·2	36·1	SW	1	29·702	29·684	29·725	29·832	44·3	35·9	SW
2	30·105	30·167	30·121	30·062	47·6	32·7	SW	2	29·856	29·815	29·588	29·486	48·1	36·4	SW
3	29·992	30·016	30·030	30·051	50·0	40·1	W	3	29·594	29·715	29·708	29·643	48·1	38·2	WSW
4	30·061	30·061	29·915	29·823	50·9	39·6	WSW	4	29·639	29·508	29·330	29·238	48·9	36·1	WSW
5	29·680	29·610	29·554	29·540	56·2	49·3	W	5	28·944	29·070	29·098	29·121	51·3	36·3	W
6	29·486	29·415	29·468	29·497	51·4	38·1	WNW	6	29·083	29·078	29·075	29·123	39·1	31·0	WNW
7	29·569	29·608	29·699	29·875	40·5	33·7	WNW	7	29·240	29·450	29·653	29·791	36·9	30·5	W
8	29·982	30·090	30·104	30·118	39·2	31·7	W	8	29·886	29·952	29·953	29·889	36·7	31·3	W
9	30·040	29·937	29·830	29·829	48·5	31·7	W	9	29·675	29·505	29·522	29·579	46·9	34·5	WSW
10	29·822	29·911	29·933	30·015	47·9	28·1	WNW	10	29·619	29·748	29·793	29·827	43·3	37·8	W
11	30·031	30·049	29·969	29·904	42·2	26·1	NW	11	29·782	29·819	29·831	29·816	44·5	37·4	WSW
12	29·859	29·773	29·317	29·199	47·7	37·8	SSW	12	29·642	29·250	28·884	28·898	41·0	33·8	SE
13	29·223	29·316	29·411	29·556	43·6	36·4	WNW	13	28·988	29·195	29·412	29·561	42·3	34·0	WNW
14	29·695	29·790	29·694	29·573	48·1	33·7	WNW	14	29·594	29·469	29·276	29·297	49·4	34·3	S
15	29·595	29·236	29·193	29·187	51·0	35·5	W	15	29·167	28·919	28·714	28·769	42·1	35·2	NE
16	29·698	29·107	29·153	29·279	44·2	35·8	S	16	28·865	28·980	29·028	29·150	41·1	36·3	ENE
17	29·376	29·533	29·582	29·638	44·5	40·2	ESE	17	29·364	29·590	29·703	29·804	43·1	39·7	ENE
18	29·653	29·710	29·711	29·779	42·1	39·3	E	18	29·817	29·829	29·820	29·849	41·0	38·0	NE
19	29·796	29·834	29·848	29·898	39·3	34·7	NE	19	29·877	29·888	29·886	29·942	39·0	36·7	ENE
20	29·900	29·949	29·941	29·934	38·3	35·0	NNW	20	29·958	29·999	29·987	29·996	37·3	31·5	N
21	29·927	29·956	29·910	29·905	35·9	29·9	N	21	29·959	29·954	29·882	29·867	32·7	26·6	NE
22	29·844	29·807	29·758	29·743	36·0	28·9	E	22	29·820	29·750	29·689	29·711	37·0	28·4	E
23	29·701	29·716	29·669	29·642	37·6	33·2	E	23	29·709	29·723	29·707	29·690	41·1	34·0	ESE
24	29·533	29·466	29·386	29·426	39·1	36·2	E	24	29·656	29·608	29·601	29·632	40·9	36·2	E
25	29·494	29·637	29·696	29·782	37·2	32·8	NE	25	29·674	29·797	29·829	29·907	37·6	35·6	E
26	29·808	29·830	29·809	29·900	37·2	32·5	ENE	26	29·730	29·974	29·987	30·075	37·7	34·7	E
27	30·052	30·229	30 345	30·400	37·2	34·6	E	27	30·169	30·271	30·315	30·343	37·3	33·3	ESE
28	30·394	30·329	30·123	29·973	46·2	32·6	ESE	28	30·270	30·106	29·891	29·757	34·4	31·7	E
29	29·901	29·925	29·863	29·811	48·5	45·2	WSW	29	29·666	29·655	29·636	29·656	44·8	33·0	SW
30	29·753	29 703	29·672	29·733	54·4	45·9	SW	30	29·614	29·542	29·526	29·592	44·1	40·3	E
31	29·774	29·871	29·969	30 076	51·5	36·6	NW	31	29·684	29·807	29·847	29·873	45·0	40·0	ENE

The Federated Institution of Mining Engineers
Transactions 1895 6

Diagram shewing the Height of the Barometer, the Maxima and Minima Temperatures and the Direction of the Wind at the Observatories of Kew and Glasgow, together with the Explosions of Fire-Damp in England and Scotland.



The firm top line is the Barometer reading at Kew, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
The dotted top line is the Barometer reading at Glasgow, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
The lower lines are the Maxima and Minima Temperatures at Kew and Glasgow, observed respectively at midnight and 9 p.m.
Kew lines are thick and Glasgow lines are thin.
The figures attached to the districts shew the Number of Deaths caused by the Explosions.

N.E. of England Institute of Mining & Mechanical Engineers
Transactions 1895 6

And.r Reid & Comp.y Ltd. Newcastle on Tyne

Vol. XLV. Plate IX

NOVEMBER, 1895.

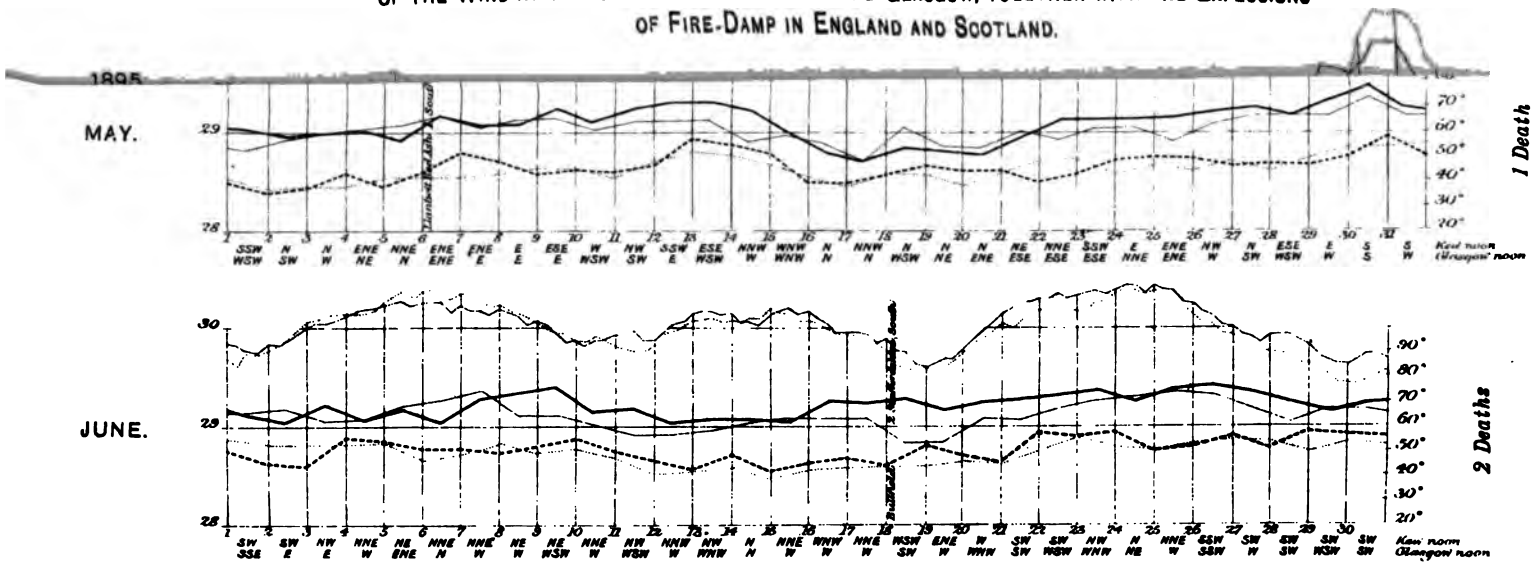
KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	30·246	30·408	30·420	30·435	54·3	38·3	SE	1	30·363	30·471	30·459	30·477	43·2	30·2	NE
2	30·357	30·247	30·075	30·049	49·5	33·0	ESE	2	30·406	30·341	30·185	30·118	43·8	35·0	NE
3	29·991	29·945	29·838	29·778	49·6	32·1	SSE	3	30·005	29·965	29·852	29·808	40·7	32·0	E
4	29·753	29·729	29·567	29·574	50·9	44·5	SE	4	29·750	29·717	29·635	29·561	42·1	39·2	ENE
5	29·549	29·504	29·501	29·251	58·0	40·9	SW	5	29·476	29·399	29·146	28·806	49·8	40·1	ESE
6	29·440	29·554	29·645	29·757	59·4	52·6	WSW	6	28·728	28·872	29·027	29·196	50·9	46·4	SW
7	29·825	29·853	29·833	29·883	59·1	50 8	SW	7	29·395	29·563	29·600	29·672	52·1	45·6	SW
8	29·944	29·944	29·840	29·745	56·2	51·1	SW	8	29·706	29·757	29·753	29·711	50·6	44·8	SW
9	29·630	29·703	29·820	29·860	56·5	45·6	NW	9	29·594	29·555	29·565	29·583	47·9	40·1	W
10	29·798	29·686	29·518	29·294	55·9	44·9	SSW	10	29·394	29·148	29·019	28·500	53·0	37·2	SSW
11	29·184	29·292	29·306	29·265	53·9	45·8	WSW	11	28·513	28·874	28·950	28·873	54·4	40·8	SW
12	29·266	29·201	29·135	29·217	50·3	42·0	SSW	12	28·806	28·762	28·821	28·842	44·5	37·4	SW
13	29·354	29·594	29·772	29·862	53·9	42·7	W	13	29·034	29·249	29·390	29·427	48·4	39·8	W
14	29·840	29·804	29·792	29·996	55·2	43·2	SW	14	29·348	29·334	29·387	29·573	46·4	39·0	WSW
15	30·038	29·986	29·711	29·695	58·6	37·1	S	15	29·694	29·560	29·140	29·244	54·7	39·1	S
16	29·710	29·675	29·606	29·965	61·6	46·2	SSW	16	29·357	29·210	29·188	29·476	48·7	38·5	SW
17	30·047	30·094	30·143	30·267	54·3	38·2	WSW	17	29·567	29·777	29·895	30·020	45·6	38·0	WSW
18	30·334	30·380	30·336	30·312	48·7	29·9	WSW	18	30·091	30·172	30·147	30·166	46·6	37·2	SW
19	30·230	30·175	30·080	30·012	47·7	38·0	ESE	19	30·126	30·108	30·008	29·939	43·2	36·8	ESE
20	29·920	29·897	29·881	29·929	51·6	46·9	SE	20	29·846	29·821	29·768	29·827	50·4	40·2	ENE
21	29·932	30·000	30·028	30·101	51·8	46·6	ESE	21	29·859	29·916	29·881	29·895	50·8	47·1	ENE
22	30·142	30·178	30·095	30·003	53·0	42·8	WNW	22	29·959	30·071	29·952	29·941	51·5	41·9	W
23	29·780	29·745	29·802	30·077	46·0	37·4	N	23	30·025	30·151	30·272	30·368	42·7	37·0	NE
24	30·183	30·231	30·174	30·187	43·9	37·8	NE	24	30·436	30·494	30·500	30·510	42·4	36·1	ESE
25	30·205	30·199	30·169	30·169	44·1	41·9	NE	25	30·494	30·497	30·432	30·395	42·9	36·6	E
26	30·130	30·138	30·065	30·053	42·0	35·6	ESE	26	30·326	30·258	30·145	30·082	44·5	41·0	E
27	29·982	29·969	29·896	29·899	47·0	35·7	E	27	29·981	29·958	29·921	29·904	43·9	40·5	E
28	29·849	29·829	29·757	29·768	50·4	37·9	E	28	29·866	29·850	29·779	29·730	45·2	41·0	S
29	29·702	29·661	29·577	29·546	52·1	49·0	SE	29	29·645	29·657	29·640	29·653	47·3	43·8	ENE
30	29·549	29·631	29·738	29·905	51·4	42·7	W	30	29·622	29·644	29·65 2	29·707	46·4	42·1	W

DECEMBER, 1895.

1	29·957	30·025	29·997	30·062	46·2	36·1	SW	1	29·702	29·684	29·725	29·832	44·3	35·9	SW
2	30·105	30·167	30·121	30·062	47·6	32·7	SW	2	29·856	29·815	29·588	29·486	48·1	36·4	SW
3	29·992	30·016	30·030	30·051	50·0	40·1	W	3	29·594	29·715	29·708	29·643	48·1	38·2	WSW
4	30·061	30·063	29·915	29·823	50·9	39·6	WSW	4	29·639	29·508	29·339	29·238	48·9	36·1	WSW
5	29·780	29·610	29·554	29·540	56·2	49·3	W	5	28·944	29·070	29·098	29·121	51·3	35·3	W
6	29·486	29·415	29·468	29·497	51·4	38·1	WNW	6	29·083	29·078	29·075	29·123	39·1	31·0	WNW
7	29·519	29·608	29·699	29·875	40·5	33·7	WNW	7	29·240	29·450	29·653	29·791	36·9	30·5	W
8	29·982	30·090	30·104	30·118	39·2	31·7	W	8	29·886	29·952	29·953	29·889	36·7	31·3	W
9	30·049	29·967	29·880	29·829	48·5	31·7	W	9	29·675	29·505	29·522	29·579	46·9	34·5	WSW
10	29·822	29·911	29·963	30·015	47·9	28·1	WNW	10	29·619	29·748	29·793	29·827	43·3	37·8	W
11	30·031	30·049	29·969	29·904	42·2	26·1	NW	11	29·782	29·819	29·831	29·816	44·5	37·4	WSW
12	29·859	29·774	29·817	29·199	47·7	37·8	SSW	12	29·642	29·250	28·882	28·898	41·0	33·8	SE
13	29·223	29·316	29·411	29·556	43·6	36·4	WNW	13	28·988	29·195	29·412	29·561	42·3	34·0	WNW
14	29·605	29·780	29·694	29·573	48·1	33·7	WNW	14	29·594	29·469	29·276	29·297	49·4	34·3	S
15	29·365	29·236	29·193	29·187	51·0	35·5	W	15	29·167	28·919	28·714	28·762	42·1	35·2	NE
16	29·208	29·167	29·153	29·279	44·2	35·8	S	16	28·865	28·950	29·028	29·150	41·1	36·3	ENE
17	29·376	29·533	29·582	29·638	44·5	40·2	ESE	17	29·364	29·590	29·703	29·804	43·1	39·7	ENE
18	29·653	29·710	29·711	29·779	42·1	39·3	E	18	29·817	29·829	29·820	29·849	41·0	38·0	NE
19	29·796	29·834	29·848	29·898	39·3	34·7	NE	19	29·877	29·888	29·886	29·942	39·0	36·7	ENE
20	29·900	29·949	29·941	29·934	38·3	35·0	NNW	20	29·958	29·999	29·957	29·996	37·3	31·5	N
21	29·927	29·956	29·910	29·905	35·9	29·9	N	21	29·959	29·954	29·882	29·867	32·7	26·6	NE
22	29·844	29·807	29·758	29·743	36·0	28·9	E	22	29·820	29·750	29·689	29·711	37·0	28·4	E
23	29·701	29·716	29·669	29·642	37·6	33·2	E	23	29·709	29·723	29·707	29·690	41·1	34·0	ESE
24	29·583	29·466	29·386	29·426	39·1	36·2	E	24	29·656	29·608	29·601	29·632	40·9	36·2	E
25	29·494	29·637	29·696	29·782	37·2	32·8	NE	25	29·674	29·797	29·829	29·907	37·6	35·6	E
26	29·808	29·850	29·899	29·909	37·2	32·5	ENE	26	29·739	29·974	29·987	30·075	37·7	34·7	E
27	30·052	30·229	30·345	30·400	37·2	34·6	E	27	30·169	30·271	30·315	30·343	37·3	33·3	ESE
28	30·394	30·329	30·123	29·973	46·2	32·6	ESE	28	30·270	30·106	29·891	29·757	34·4	31·7	E
29	29·901	29·925	29·863	29·811	48·5	45·2	WSW	29	29·666	29·655	29·636	29·656	44·8	33·0	SW
30	29·753	29·763	29·672	29·733	54·4	45·9	SW	30	29·614	29·542	29·526	29·592	44·1	40·3	E
31	29·771	29·871	29·969	30·076	51·5	36·6	NW	31	29·684	29·807	29·847	29·873	45·0	40·0	ENE

The Federated Institution of Mining Engineers
Transactions 1895 6

DIAGRAM SHEWING THE HEIGHT OF THE BAROMETER, THE MAXIMA AND MINIMA TEMPERATURES AND THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW AND GLASGOW, TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND AND SCOTLAND.



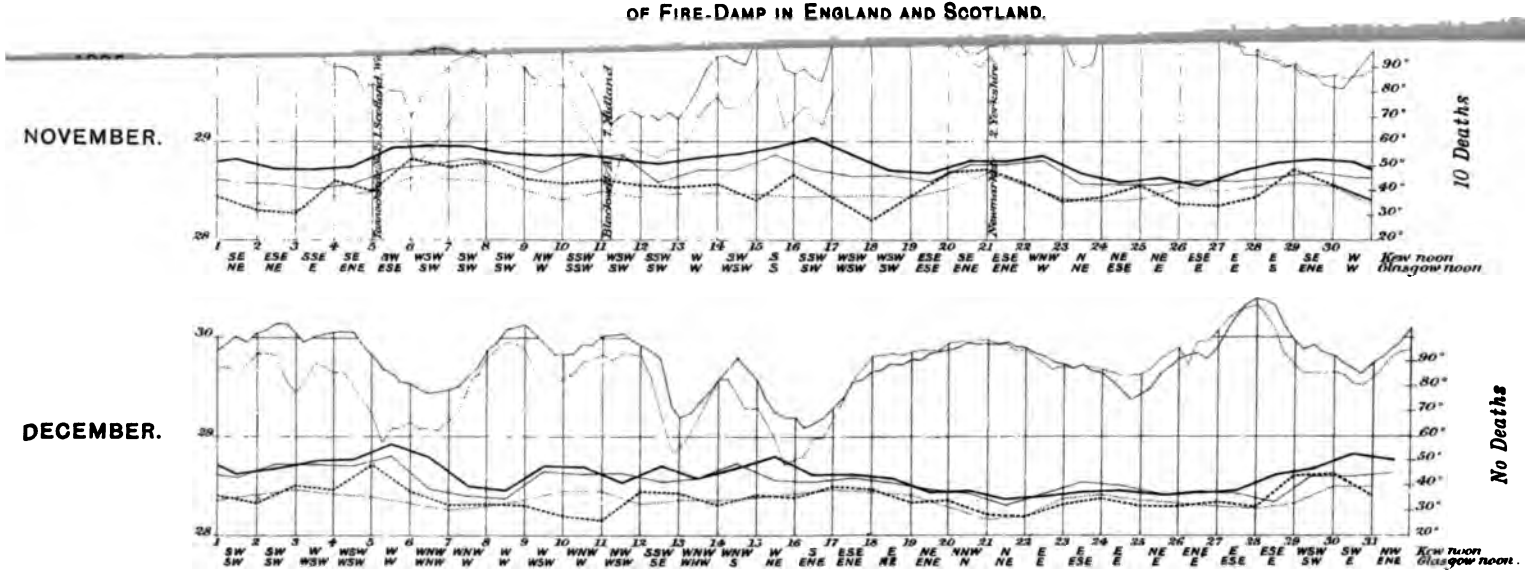
The firm top line is the Barometer reading at Kew, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
The dotted top line is the Barometer reading a Glasgow, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
The lower lines are the Maxima and Minima Temperatures at Kew and Glasgow, observed respectively at midnight and 9 p.m.
Kew lines are thick and Glasgow lines are thin.
The figures attached to the districts shew the Number of Deaths caused by the Explosions.

Mine. of England Institute of Mining & Mechanical Engineers
Transactions 1895

And^{w} Reid & Comp^{y} L^{td} Newcastle on Tyne

VOL. XLV. PLATE IX

DIAGRAM SHEWING THE HEIGHT OF THE BAROMETER, THE MAXIMA AND MINIMA TEMPERATURES AND THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW AND GLASGOW, TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND AND SCOTLAND.



The firm top line is the Barometer reading at Kew, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
The dotted top line is the Barometer reading at Glasgow, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
The lower lines are the Maxima and Minima Temperatures at Kew and Glasgow, observed respectively at midnight and 9 p.m.
Kew lines are thick and Glasgow lines are thin.
The figures attached to the districts shew the Number of Deaths caused by the Explosions.

...h of England Institute of Mining & Mechanical Engineers
Transactions 1895-6

And^w Reid & Comp^y L^td Newcastle on Tyne

VOL. XLV. PLATE X.

INDEX TO VOL. XI.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil, and Mechanical Engineers.

S.—Mining Institute of Scotland.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

Aber colliery, electric coal-cutting, 501.
Abergele, North Wales, 553, 554.
Accidents, fatal and non-fatal, from explosions of fire-damp or coal-dust, 1895, 528, 651, 652.
— from gas in wells, 265, 266, 267.
Accounts, M., 488.
—, S., 87.
Acetylene lamp, 573.
Acton hall collieries, 121.
— — —, notes on the sinking of No. 1 pit, with special reference to the thinning out of the Silkstone and Beeston coal-seams.—Discussion, 162, 233.
Accumulators, Benados, 41.
Adderley Green, pebble beds, 562.
ADDIE, ROBERT, election, S., 235.
Adjustable piston-rings, 118.—Discussion, 120.
Advantages of coal-cutting by machinery, 201.
— — compressed air, 602.
Adwalton black bed, 164.
Africa, gneissic rocks, 349.
—, gold-bearing rocks, 348.
—, South, geological description of the gold-mines of the Transvaal, 378.
—, —, gold-fields of Matabeleland, 29.—Discussion, 38.
—, —, gold-mining, 263.
After-damp, 502, 503, 505, 506, 507, 508, 509, 510, 511, 512, 539.
Agnes Munro gold-mine, South Africa, 418.
Agricultural labourers, comparative mortality, 244, 253.
AGRICOLA, GEORGE, quoted, 251.
Air and gas, continuous and automatic apparatus for taking samples, 619.
Air-compressing plant, champion reef gold-mine, India, 359.
Air-compressors, 180, 181.
— —, cost, 199, 200.
— —, Ingersoll, 81.
AITKIN, HENRY, quoted, 91, 92.
—, *recovery of bye-products in the manufacture of hard coke*, 174.
—, *treatment of timber for use in mines*, 92.
Albion colliery, experiments with coal-dust, 508.
Alcohol and gaseous poisoning, 275.
Alcoholism, coal-miners, 245.
Aldwarke main collieries, 124.
— — —, experiments with coal-dust, 508.
Alexandra estate, South Africa, 440.
ALFORD, C. J., quoted, 348.
Alleghany mountains, U.S.A., 145.
ALLEN, CHAS. M., quoted, 369.
ALLEN AND KAPP, dynamos, Deptford station, 465.
Alteration of rules, C., 127.
— — —, M., 227.
Allier river, France, 385.
Alluvial deposits, India, 350.
Alveley, 22.
Amalgamation, tailings costs, Indian gold-mills, 365.
Amatola, South Africa, 419, 421.
America, U.S.A., exportation of rails, 260.
Ammonia, liquid, 298, 300, 301, 302.
Amygdaloidal diabase, South Africa, 397, 398, 430.
— porphyrites, South Africa, 395, 451.
Anaconda mine, U.S.A., fire, 93.
Analyses, black-damp, 272.
—, coal, Derbyshire, 544.
—, —, Dover, 544.

Analyses, coal, Lancashire, 544.
—, —, Midland, 544.
—, —, Newcastle, 544.
—, —, North of England, 544.
—, —, South Wales, 544.
—, —, Yorkshire, 544.
—, — washed, 58.
—, coke, Yorkshire, 61.
—, fire-damp, 611.
—, furnace-gases, 322, 326, 332.
—, gas from wells, 265, 267, 268.
—, gases from an explosion, 538.
—, mine-atmospheres in Donetz coal-field, Russia, 620.
—, mine-gases, 272.
Ancient copper-mines of Sinai, 598.
— gold-mining, Matabeleland, 31, 32, 33, 34, 37, 38.
ANDERSON, SIR JAMES, quoted, 262.
ANDERSON, T. SCOTT, electric-welding, 40.—Discussion, 52, 230.
Angelo gold-mine, South Africa, 418.
Anglesea, coal-field, 144, 552, 554.
Annagher, Coal-island, 151.
Annaghone colliery, Ireland, 151, 152.
Annual report of council, M., 486.
— — — —, S., 85.
Anthracite, Austria, Bohemia, in Permian rocks, 587.
—, Norway, Kongsberg, 428.
Antigrisou, 3.
Antimony, 160.
—, South Africa, 440.
Antrim, Ireland, 152.
—, —, Lough Neagh beds, 153.
Antwerp to Bombay or Calcutta, freights, 260, 261.
Anzin collieries, sinking of Vicq pits, 213.
Apex gold-mines, South Africa, 418.
Apparatus, continuous and automatic for taking samples of air or gas, 619.
— for breathing noxious gases, 560.
— — promoting the circulation of water in boilers, 582.
Arabs and India, 346.
Arc system of electric welding, 40, 41, 42, 49, 50, 53, 54, 231.
Archæan deposits, South Africa, 399.
— rocks, North Wales, 552, 553.
ARCHER, OAKELEY, election, N.E., 215.
Ardeer powder, 166, 168.
— —, composition, 167.
Ardennes, porphyroids, 385, 386.
Argentine Republic, ore-deposits of San Luis, 649.
Argentine, U.S.A., consolidated Kansas City smelting company, 376.
Argillaceous rocks, India, gold-bearing, 347.
— schists, South Africa, 399.
Argon, 256.
—, from a well, 265.
Armatures, 312, 313.
ARMSTRONG, THOMAS HENRY, election, N.S., 103.
ARMSTRONG, THOMAS HENRY, rocket oil-engine.—Discussion, 170.
ARNOLD boiler, 80, 81.
ARNOTT, THOMAS, member of council, election, S., 88.
—, *treatment of timber for use in mines*, 90, 91
Arsenic, South Africa, 432.
Arsenical-pyrites, India, 351.
Ashwood, boring, 25.
ASHWORTH, JOHN, election, N.E., 173.
ASHWORTH, JAMES, oil-burner, 105, 106, 107.
—, Mueseler safety-lamp, 108.
Asphalt and petroleum, Crédo deposit, France, 573.
Asthma, miners', 241, 242.
Astley colliery, electric coal-cutting, 501.
Asturias, Spain, occurrence of mercury, 639.
Atherstone, Warwickshire, 13.
ATKINSON, A. A., *adjustable piston-rings*, 121.
—, *electric coal-cutting on longwall faces*, 501.
—, vice-president, election, M., 490.
ATKINSON, J. B., quoted, 502, 507.
ATKINSON, W. N., *causes of death in colliery explosions*, 513, 519.
—, examiner in technical education, Staffordshire county council, 572.
—, prize for paper, 1.
—, quoted, 271, 273, 502, 507.
—, *report of Explosives Committee*, 218.
—, *suffocative gas met with in wells*, 275.
Auriferous conglomerates, India, 348.
— — or banket beds. South Africa, 378. 379, 380, 381. 382 383, 384, 386, 387. 388, 391, 392, 393, 394, 395, 397, 398, 399, 400, 402, 405, 406, 411, 413, 417, 443, 453.
— gravels of Upper Columbia river, British Columbia, 626.
— placers, California, U.S.A., 439.
— pyrites, Rapazos mine, Brazil, 384.
— —, South Africa, 409, 431, 432, 433, 453, 459.
— quartz, Australia, 439.
— —, South Africa, 397.
— slates, South Africa, 397.
— vein-quartzes, South Africa, 457.
Aurum company, South Africa, 430.
Australia, auriferous quartz, 439.
—, — quartzites, 405.
—, fire at Broken hill mines, 93.
—, pliocene system, 434.
—, Western, gold mining, 628.
Austria, anthracite in permian rocks of Bohemia, 587.
Automatic apparatus for taking samples of air or gas, 619.
Awards for papers, 1.
Axle box for mine tubs, 633.
Ayrshire, Southern, coal-fields. — Discussion, 89.
AYTON, H., explosives committee, 218.

Babcock and Wilcox, boilers, 180.
Backhouse, Frank Herbert, election, N.E., 215.
—, vice-chairman, election, W.A B., N.E., 516.
Bagworth colliery, Leicestershire, 13.
Bailes, W., *causes of death in colliery explosions*, 560.
Bailey, Edward Trenholm, election, N.E., 216.
Baily, —, electric power-transmission in mines, 601.
Baird, Dugald, duty of pumping-engines, 94.—Discussion, 235.
—, *Müller smoke and gas-mask*, 248
Bakers, comparative mortality, 243, 244.
Bakerian lecture, Rücker and Thorpe, 343.
Bala beds, North Wales, 553.
Balaghât Mysore gold-mines, Mysore, India, statistics, 363, 366, 367.
Balance with water-brake for lowering gob-material, 634.
Balance-rope for winding-engines, 72, 73, 74, 208.
Balcombe, Mid Sussex, accident from gas in well, 266, 267.
—, —, well, analysis of gases, 268, 269.
Bald, --, quoted, 256.
Bald, Prof. V., quoted, 346.
Ballot voting, M., 491.
Ballycastle, coal-seams, 152.
Balmoral gold-mine, South Africa, 418.
Bangalore branch, Madras railway, India, 355.
Bangor beds, North Wales, granite veins, 552.
— station, North Wales, archæan rocks, 552.
Bank, near Calverley, boring, 25.
Bankets or auriferous conglomerates, South Africa, 378 to 461.
Bannister, David, *adjustable piston-rings*, 120, 121.
—, *methods of closing the tops of upcast winding shafts*, 123, 124.
Barberton, Transvaal, 378.
Barlow, J. W., *how a mine may be dry but not dusty*, 136.
Barometer, thermometer, etc., readings, 1895, 651.
Barometric changes, effect of, in wells, 266, 267, 269, 270, 276, 277.
Barr beacon, 17.
Barrels, steel, electric welding, 51.
Barrois, Dr., quoted, 409.
Barrow hill, Leicestershire, 13.
Barrowman, James, health conditions of coal-mining, 240.—Discussion, 248.
—, *treatment of timber for use in mines*, 91.
Barton,—, burner, 105, 106, 107, 109, 110.
Basalt, South Africa, 385.
Batley, Beeston coal-seams, section, 165.
Battery extension gold-mine, South Africa, 429.
Battery reef, South Africa, 384, 395, 427, 429.
Baudry, —, balance with water-brake for lowering gob-material, 634.
Bayer shaft and adjacent portion of Pilsen coal-basin, Bohemia, geology, 590.
Bearer system of conveyance, 253.
Beath, Fifeshire, phthisis, 245.
Beaufort beds, South Africa, 400.
— group, South Africa, 401.
Beaumaris, North Wales, granite-veins, 552.
Beche, Sir H. de la, quoted, 543.
Bechuanaland, South Africa, 378.
Bedford, Alfred, election, M., 227.
Bedford Leigh, Lancashire, zechstein permian measures, 27, 562.
Bedworth, Warwickshire, 13.
—, —, bore-hole, 19.
Beehive coke-ovens, 84.
Beeston coal-seam, sections, 165, 166.
— — —, thinning out at Acton hall colliery, 162, 233.
Belgium, coal-fields, 542.
—, competition in iron and coal, 260.
—, magnetic survey, 343.
—, palæozoic fault, 543.
—, railway rates, 261.
Belinfante, L. L., 378.
Belingwe district, Matabeleland, 37, 460.
Bell, W. R., and E. McGowan, haulage at Wearmouth colliery, 221.
Belleville water-tube boilers, 325.
Bellite, 167.
Benardos accumulators, 41.
— system of electric welding, 40, 41, 42, 49, 50, 53, 54.
Bengal, India, gold-mining, 347.
Bennett, A. W., *electric welding*, 53, 231.
—, *electrical machinery for mines*, 125, 228.
—, *electricity in coal-mines*, 316.
—, *Roth method of firing shots*, 161.
—, telephonic communications in coal-mines.—Discussion, 124.
Benoni gold mines, South Africa, 418, 419.
Benson, P., election, S., 88.
Benson, T. W., Brancepeth colliery accident, 174.
Bentrop, W., endless-rope haulage at Roland colliery, Rhenish, Prussia, 633.
Berezite, Berezovsk, Urals, Russia, 380.
Berezovsk, Urals, Russia, berezite, 380.
Beringer, R. E., election, S.S., 572.
Berlin, powdered coal-firing, 324, 326, 328, 329, 334, 337.
Bermondsey works, Wegener apparatus, 325, 333, 334, 335, 337.
Bernard, Dr. Claud, quoted, 504.
Berne, —, expansion in winding-engines, 604.
—, quoted, 213.

Berryman feed-water heater, 236.
Berthelot, Prof., ancient copper mines of Sinai, 598,
Berthon transmitter, 124.
Bertrand, Marcel, quoted, 392.
Bessemer steel, electric-welding, 474.
Bestwood colliery, Nottinghamshire, 339, 340.
— —, —, fencing-gates, 157.
Bicarbonate of sodium, 167.
Bidstone, pebble-beds, 27.
Biesbok spruit, South Africa, 426.
Bigg-Wither, H., *report of the explosives committee*, 176.
Bi-metallic mining company, Phillipsburg, Montana, U.S.A., 373.
Binns, G. J., *eastern limits of Midland coal-field*, 18.
—, *how a mine may be dry but not dusty*, 137.
Bird reef, South Africa, 384, 387, 395, 419, 421, 427, 429.
Birkdale, Lancashire, 555.
Birkenhead, Bidstone, 27.
Birley moor, 81.
— vale, coke-ovens, 84.
— — colliery, 81.
Birmingham, electric welding plant, 41, 54.
—, German competition, 260.
—, new collieries, 20.
—, Sandwell park, 16.
Blaauwbank, South Africa, 382.
Black coombe, North Wales, 552, 553.
Black-band ironstone. 26.
Black-damp, composition, 272.
— —, experiments at Burghlee pit, Midlothian, 271.
— — of coal-mines, observations on, 265. —Discussions. 273.
Black reef series, South Africa, 382, 384, 395, 396, 397, 398, 399, 402, 426, 432, 438, 451, 452, 453, 458.
Blacksmiths, comparative mortality, 243, 244.
Blackwell colliery, 539.
— —, coal-dust, 176.
— —, electric coal-cutting, 501.
— —, explosion, 138, 526, 527.
Blake-Marsden, stone-breaker, Ooregum gold-mines, India, 359.
Blakemore, W., coal-cutting by machinery, 179.—Discussion, 204.
Blane, James, election, S.S., 572.
Blasting efficiency of explosives.—Discussion, 62.
— in fiery mines, dangers of 608.
— machine-cut coal, 191, 197.
Blasting-gelatine, 3.
Blasting-powder, 6, 8, 62, 167, 218, 219, 537, 539.
— —, Cleveland mines, 274.
Bleichsteiner, F., coal-dust furnaces, 575.
Blende, South Africa, 397, 453.
Bletchley. Buckinghamshire, boring, 14.
Blinkpoort, South Africa, 426.
Blocking coal-seam, 163, 166.
Blowing wells, Northallerton, 269, 274, 276.
Blown-out shots, 3, 4, 5, 8, 168, 219, 536, 537, 539.
Blue marls, Wexford, 153.
Bo'ness dock, N.B., 261.
Bohemia, Austria, anthracite in permian rocks, 587.
—, —, geology of portion of Pilsen coal-basin, 590.
—, —, experiments with powdered lignite, 326.
Böhm, Josef, explosion at Hohenegger shaft, Karwin, Austria, 605.
Boiler efficiency, 322, 323, 332.
— repairs, electric welding, 44, 51.
Boilers, Arnold, 80, 81.
—, Babcock and Wilcox, 180.
—, Birley collieries, 84.
—, Cornish, 237, 324, 326, 331, 332.
—, —, Mysore gold-mines, India, 358, 359.
—, Lancashire, 324, 325, 326, 328, 329, 332, 333, 334, 335, 338, 499.
—, —, cost, 199, 200.
—, —, Moss hall collieries, 558.
—, —, Park collieries, 556.
—, multitubular, 324.
—, —, Mysore gold-mines, India, 359.
—, Nunnery collieries, 80, 81.
—, powdered coal for firing: Wegener and other systems, 321.—Discussion, 332.
—, water-tube, 324, 332.
—, Wearmouth colliery, 225.
— with small water-tubes, expansion-dampers for furnaces. 581.
Bokkeveld beds, South Africa, 383, 455.
Boksburg, South Africa, 400.
—, — —, Brakpan colliery, 401.
Bombay, freights from Antwerp, 260.
—, — — Glasgow, 261.
—, — — London, 260.
—, gold-bearing schists, 347.
Bonanza gold-mine, South Africa, 394, 412, 413, 417, 443, 444.
Bonneted safety-lamps, 84.
Bonser, Harold, *methods of closing tops of upcast winding-shafts*, 122, 123.
—, —, *mining explosives*, 166, 169.
Bonthrone, Barclay, election, S., 88.
Boring, electric, 45.
—, Raky system, 582.
— Company, Vivian diamond, 340.
— machine, Jeffrey, 197.
Borings, Ashwood, 25.
—, Bedworth, 19.
—, Bletchley, 14.
—, Burford, 543.
—, Calais, 542.
—, Calverley, 25.
—, Chatham, 542.

Borings, Cheshunt, 14.
—, Coventry corporation, 562.
—, Crossness, 543.
—, Culford, 14.
—, Dover, 542.
—, —, fossil imprints, 548.
—, —, Great fall, Shakespear cliff, 540, 544.
—, Goldthorn hill, 25
—, Gosford waterworks, 25.
—, Highgate common, 25.
—, Himley park, 25.
—, Leicestershire, Desford, 13.
—, Liverpool and Manchester, 561.
—, Meux's, 543.
—, Netherseal colliery company, 12, 18.
—, Northampton, 14.
—, Northamptonshire, Orton, 13.
—, Northwich, 21.
—, Rhyl, North Wales, 554.
—, Richmond, 543.
—, Ruddington, 154.
—, Sheerness, 542.
—, Stutton, 18, 20.
—, Swindon, 25.
—, Trentham, 562.
—, Turnford, 543.
—, Ware, 14, 543.
—, Weeley, 18.
—, White cross, 25.
Bothas reef, South Africa, 384, 389.
BOULANGIER, —, Crédo deposits of asphalt and petroleum, France, 573.
BOULDEN, FREDERICK, election, M., 485.
BOULTON, J. W., improved wheels, 282.
Bourbonnais, France, 385.
BOVILL, GEORGE HINTON, quoted, 254.
BRADY, F., G. P. SIMPSON, and NATH. R. GRIFFITH, Kent coal-field, 540.—Discussion, 550.
BRAIN, F. W., election, S.S., 563.
Brake and pulley, for self-acting inclines, 634.
Brakpan colliery, Boksburg, South Africa, 401.
Brancepeth colliery, explosion, 174, 502, 503, 526, 527.
BRANCKER, RICHARD, election, M., 485.
Brass, electric-welding, 473.
Brazil, auriferous pyrites, Rapazos mine, 384.
—, gold-bearing hæmatites, 383.
—, granites, etc., 383.
Brazing, electric-welding, 50.
BREAKELL, JOHN S., election, N.E., 173.
BREE, JOHN, election, N.E., 216.
Bremen, water-tube boilers, 324.
Brick-kilns, Hoffman, 81.
— —, Sercombes, 81.
Brickyard, Spinney borehole, Nottinghamshire, 339.
Brick-works, Moss hall coal company, 557.
Brick-works, Nunnery collieries, 81.
Bridgenorth, 23, 25, 26.
BRIERLEY, BRANDON TALFOURD, election, N.E., 215.
Brightside, Sheffield, electric-welding, 76.
Briquette works, coal-dust firing, 574.
Brimington, Nottinghamshire, 343.
BRISSE, —, quoted, 400.
Bristol, coal-field, 144, 149, 540.
British Columbia, auriferous gravels, Upper Columbia river, 626.
— India, gold-mining, 346.
— made explosives, 167.
— South Africa company, Matabeleland, 460.
Broad oaks ironworks, 84.
Broken hill mines, fire, 93.
Bromine process for extraction of gold, Cassell-Hinman, 622.
BROWN, EDWARD, *electric-welding*, 231.
—, *electrical machinery for mines*, 229.
—, *lead and lap of winding and other engines*, 233.
—, *treatment of timber for use in mines*, 232.
BROWN, HORACE F., mechanical roasting of ores, 369.
—, system of furnaces, 370, 373, 376.
BROWN, M. WALTON, barometer, thermometer, etc., readings for year 1895, 651.
—, *coal-cutting by machinery*, 204.
—, *eastern limits of the Midland coal-field*, 19.
BROWN, —, quoted, 560.
Brown-coal briquette works, dust-firing, 574.
Browniona, Brongt., South Africa, 400.
BRZEZOWSKI, FRANZ, dangers of blasting in fiery-mines, 608.
—, quoted, 4, 5.
Buckinghamshire, 14.
Buffelsdoorn, South Africa, 390, 392, 393, 396, 406, 409, 428, 429, 430, 432, 457.
— gold-mine, South Africa, 440.
— reefs, South Africa, 410, 427, 433.
Building-stones, Cheshire, 27.
Bull pumping-engine, tests, 100, 101.
Buluwayo, Matabeleland, 29, 30, 460.
BUNNING, T. W., quoted, 560.
BUNSEN burner, 335.
Bunter formation, Liverpool, 562.
— —, lower, 25, 26.
— —, —, Nottinghamshire, 339, 340, 343.
— pebble beds, 26, 27.
— sandstone, lower, 23, 27.
Burford, Oxfordshire, boring, 543.
—, —, —, carboniferous rocks, 543.
—, —, —, new red sandstone, 562.
Burgers reef, South Africa, 429.
Burghlee pit, analysis of gas, 272.
— —, experiments with black-damp, 271.
Burmah, gold-mining, 346.
Burslem, Sneyd colliery, 70.

Bush mill, accident, 229.
Bushmans hoek, South Africa, coal-deposits, 401.
Butchers, comparative mortality, 244.

Cables, Lang laid, 372.
CADELL, H. M., member of council, election, S., 88.
Cadzow colliery, experiments on timber, 90.
Cahir, Ireland, pipe-clays, 153.
Calais, boring, 542.
Calcareous rocks, South Africa, 396.
— sandstone, Scotland, 89.
Calcining-furnaces, 369, 370.
Calcutta, freights from Antwerp, 260.
—, — — London, 260.
California, U.S.A., auriferous placers, 439.
—, —, — quartzites, 405.
—, —, pliocene system, 434.
CALLON, PROF., quoted, 213.
Calorific value of fuel, determining, 583.
Calorimeter for determining heating value of coals, 584.
Calumet, Lake Superior, copper-bearing conglomerates, 458.
Calverley, boring, 25.
Cambrian, 12, 13, 14.
—, North Wales, 553.
—, South Africa, 399.
—, Suffolk, 15,
—, lower, conglomerate, North Wales, 552.
Cambro-Silurian, 14, 17.
Camerton colliery, Somersetshire, explosion, 526.
CAMPBELL, CHARLES, 482.
Camp Floyd mining district, Utah, U.S.A., 627.
Canada, Ingersoll rock-drill company, 180.
Candles, cost, India, 353, 364.
Cannock, coal-field, 149.
—, sinkings, 303, 305.
— and Huntington sinking pit, 24.
— — Rugeley collieries, coal-cutting machines, 497.
— — — —, underground haulage, 564.
— — — — —, electric coal-cutting, 501.
— wood mine, underground haulage, 564.
CANTRILL, T. CROSBEE, *depth of productive coal-measures between Warwickshire and Lancashire coal-fields*, 22, 26.
—, quoted, 24, 26.
Cape Breton, coal-cutting by machinery, 193, 198, 201.
Cape colony, clay slates, 383.
— —, coal-deposits, 401.
— —, Gatsrand quartzites, 398.
— —, gold-bearing rocks, 399.
— —, Karoo beds, 401.
— —, micaceous shales, 383.
Cape of Good Hope, fossils, 397.
Cape Town, South Africa, 393, 396, 398.
— —, — —, railway to Johannesburg, 401.
Capeldrae colliery, fire, 92.
CAPELL, G. M., fan, 81.
Caradoc beds, North Wales, 553.
Carbon dioxide, 323, 326, 328, 329, 332, 333, 337, 504, 533, 537, 539.
— —, Cleveland mines, 274.
— —, from wells, 265, 267, 268, 270, 271, 274, 275, 276, 277.
— —, outbursts, 584, 585.
Carbon monoxide, 165, 169, 273, 274, 327, 332, 502, 503, 504, 505, 506, 507, 508, 510, 511, 513, 533, 537, 538, 539, 560.
— — poisoning, 504.
— — —, symptoms, 504, 506.
Carbonaceous venules, South Africa, 428.
Carboniferous deposits of Karoo, South Africa, 379.
— fossils, South Africa, 396, 397, 401.
— limestone, 14.
— —, Mendip hills, 562.
— —, North Wales, 553, 554.
— —, South Africa, 455.
— strata, 13, 14, 16, 17, 27, 145, 148, 154.
— —, Burford, 543.
— —, Ireland, 150, 151, 152.
— —, South Africa, 398, 399.
— —, Suffolk, 15.
— —, lower, 9, 11, 21, 23, 26.
Carbonit, 3, 166, 167, 168.
—, composition, 167.
Carcoor ghâts, India, 349.
Carmichael shaft, Champion reefs gold-mine, India, 361.
Carnedd-Llewelyn, North Wales, 553.
CARPENTER, R. C., calorimeter for determining heating value of coals, 584.
Carpenters, comparative mortality, 244.
Cartridges, grisounite, delayed ignition, 610.
Cason black property, South Africa boring, 418.
Cassel colliery, Daggafontein, South Africa, 401.
CASSELL-HINMAN, bromine process for extraction of gold, 622.
Causes of death in colliery explosions, 502.—Discussion, 513, 519, 559.
Central plateau, France, 425.
— provinces, India, gold-mining, 346.
— Rand, South Africa, 406, 407, 411, 419, 454.
Chairman, election, W.A.B., N.E., 516.
Chalcopyrite, South Africa, 404, 440, 453.
Chalk formation, Harwich, 15.
— —, Suffolk, 15, 167.
CHALMERS AND HATCH, quoted, 395.
Chamber of mines, South Africa, statistics, 449.
CHAMBERLAIN, JOSEPH, 540.
CHAMBERS, A. M., member of council, election, 490.

CHAMBERS, J. E., vice-president, election, M., 490.
CHAMBERS, W. HY., member of council, election, M., 490.
CHAMBERS, W. HOOLE, *alteration of rules*, M., 491.
Champ d'or gold-mine, South Africa, 422, 427, 438, 449.
— — reef, South Africa, 389, 405, 410.
Champion reef, Madras, India, 356.
— — gold-mines, India, air-compressing plant, 359.
— — — —, —, statistics, 361, 362, 363, 366, 367.
Channel tunnel, 540, 541.
CHANNING, J. PARKE, election, N.E., 173.
CHAPUY, —, southern portion of Valenciennes coal-field, France, 589.
Charnwood forest, 9, 13, 342
CHARLETON, A. G., Indian gold-fields, 345.
CHARLTON, WILLIAM JOHN, election, N.E., 173.
Chartered Company of British South Africa, Matabeleland, 29, 30, 31, 33.
Charterhouse laundry well, analysis of gas, 268.
Chatham, boring, 542.
Cheshire, carboniferous ridge, 27.
—, coal-field, 144.
—, coal-washing plant at Wirral colliery, Neston, 55.—Discussion, 59.
—, keuper formation, 27.
—, new red sandstone, 562.
—, triassic rocks, 554, 562.
—, central, 342.
—, north, permian measures, 27.
—, —, zechstein permian, 26.
Cheshire-Lancashire, coal-fields, 144.
Cheshunt, Buckinghamshire, boring, 14.
CHEWINGS, CHARLES, election, N.E., 174.
Chillington, Codsallwood, 25.
Chimes gold-mine, South Africa, 402, 403, 420, 421.
— west, South Africa, 419.
Chlorination-barrels, 374, 375.
Chlorine, 159, 160, 161.
— monoxide, 161.
Chlorite, South Africa, 412.
Chloritic rocks, India, gold-bearing, 347.
— schists, Madras, India, 355.
— —, North Wales, 552.
— —, South Africa, 399, 420.
Choke-damp, specific gravity, 266.
— — of wells, 266, 267, 268, 269, 270, 271, 275, 276, 277.
Chota-Nagpur, India, gold-mining, 347.
CHURCHILL, LORD RANDOLPH, quoted, 460.
CHURTON, THOMAS HARDING, election, M., 227.
Cinder hill colliery, coal-dust, 129, 134, 135, 136, 140, 142.
Cinderella gold-mine, South Africa, 418.
City and Suburban gold-mine, South Africa, 412, 417, 438, 443, 449.
— — — reef, South Africa, 394.
Clacton-on-the-Sea, 18.
Clare, Ireland, coal-measures, 151.
CLARK, W. F., member of council, election, 572.
CLARKE, T. B. A., electric coal-cutting on longwall faces, 492. - Discussion, 501.
—, *electrical machinery for mines*, 228.
Clay mines, inflammable gases, 613, 614.
Clay-slate series, South Africa, 382, 383, 399.
CLAYTON. HAROLD, 212.
Clayton, Yorkshire, coal-seams, 162, 163.
Cleaning of coal, 255.
Cleckheaton, Beeston coal-seam, sections, 165.
Clee hills, 24.
CLELAND, E. DAVENPORT, election, N.E., 216.
Clent hills, section, 16.
Clergymen, comparative mortality, 243, 244.
Cleveland mines, blasting-powder, 274.
— —, carbonic acid, 274.
— —, petroleum engines, 274.
Clifton colliery, Nottinghamshire, 339, 340, 341, 343, 344.
Climate, Wynaad district, India, 354.
Climax rock drills, 359.
CLIVE, LORD, quoted, 346.
Closing tops of upcast winding-shafts.—Discussion, 122.
CLOUGH, SAMUEL, election, M., 485.
CLOWES, DR. FRANK, hydrogen lamp, 273.
—, quoted, 248.
Clwyd vale, North Wales, 553, 554.
Clyde coal-field, 144.
Coal, analysis, Derbyshire, 544.
—, —, Dover, 544.
—, —, Lancashire, 544.
—, —, Midland, 544.
—, —, Newcastle, 544.
—, —, washed, 58.
—, —, Welsh, 544.
—, —, Yorkshire, 544.
—, anthracite, Austria, Bohemia, 587.
—, combustion in air, 580.
—, compressed air, 499, 500.
—, calorimeter for determining heating value, 584.
—, English and South African, 401.
—, Nixon navigation, 323.
—, outputs of United Kingdom in 1855 and 1894, 240.
—, powdered, experiments with, 326, 328, 329.
—, —, for firing steam-boilers Wegener and other systems, 321.—Discussion, 332.
—, —, for firing, 576.
—, Scotland, prices, 259.

Coal, South Africa, Boksburg, 401.
—, — —, English and Welsh, 401.
—, — —, Middelburg, 401.
—, — —, Transvaal, 597.
—, suited for Royal navy, analyses, 544.
—, washed and unwashed, analyses of coke, 61.
—, Welsh and South African, 401.
Coal-ash, fusibility and composition, 586.
Coal-boring association, eastern counties, 15, 20.
Coal-cutting, electric, on longwall-faces, 492.—Discussion, 501.
— — by compressed air, 499, 500.
— — — machinery, 179.—Introduction, 179.—Stanley header, 181.—Mitchell longwall machine, 183.—Ingersoll-Sergeant machine, 185.—Yoch machine, 193.—System of working, 197.—Costs, 198.—General conclusions, 201.—Discussion, 204.
— — — —, Illinois, U.S.A., 258.
— — — —, quality, 192.
— — machinery, 257.
— — —, cost of plant, 199, 200.
Coal-dust, Blackwell colliery, 176.
— —, Cinderhill colliery, samples, 135.
— —, experiments with explosives at Aldwarke main colliery, 508.
— —, Haswell colliery explosion, 220.
— —, laying of, 128, 134.
— —, notes on explosion of, 536.—Discussion, 539.
— —, Propfe mill for, 574.
— —, Whitehaven, 178.
— —, Wigan, 178.
— — and fire-damp, 219.
— — — propagation of flame, 503, 507.
— — — shot-firing, 137.
— —, firing in brown-coal briquette works, 574.
— — furnaces, 575.
— — or fire-damp, accidents from explosions, 1895, 528, 529, 651, 652.
Coal-fields, Anglesea, 144, 554.
— —, Austria, Bohemia, Pilsen, 590.
— —, Ayrshire, southern.—Discussion, 89.
— —, Belgium, 542.
— —, Bristol, 149, 540.
— —, Cannock, 149.
— —, Cheshire, 144.
— —, Coalbrookdale, 24.
— —, concealed, 147.
— —, Connaught, 151.
— —, Clyde, 144.
— —, Dean Forest, 11, 149, 543.
— —, Derbyshire, 9, 19, 20, 143, 144, 153.
— —, Flintshire, 144.
— —, Forest of Dean, 11, 149, 543.
— —, — — Wyre, 22, 23, 24, 25.
— —, Forth, 144.
— —, France, Valenciennes, southern portion, 589.
Coal-fields, Germany, Saar, testing return air-currents, 615.
— —, Great Northern, 144.
— —, Ireland, 144, 147, 155.
— —, Kent, 144, 540.—Discussion, 550.
— —, Kilkenny, 554.
— —, Lancashire, 21, 554.
— —, —, south, 147.
— —, Leicestershire, 9, 12, 18, 19, 144.
— —, Midland, 144, 146, 147, 148, 149, 153, 154.
— —, —, eastern limits of, 9.—Discussion, 17.
— —, North Midland, 153.
— —, Nottinghamshire, 9, 19, 20.
— —, —, southern limit, 339.—Discussion, 341.
— —, Oxfordshire, 144.
— —, Pas-de-Calais, 540.
— —, Russia, Donetz, 593, 594.
— —, —, —, composition of mine-atmospheres, 620.
— —, Shropshire, 11, 19.
— —, Somersetshire, 11, 149, 542, 543.
— —, South Africa, 401.
— —, — —, Johannesburg, 401.
— —, — —, Matabeleland, 30.
— —, — —, Transvaal, 401.
— —, South Midland, 20.
— —, — Staffordshire, 9, 11, 15, 16, 17, 19, 20, 144, 154.
— —, — Wales, 149, 543.
— —, — Yorkshire, 19, 143.
— —, Southern Ayrshire.—Discussion, 89.
— —, Spain, Puertollaño, 596.
— —, —, Villanueva, 596.
— —, Staffordshire, 19, 20.
— —, Tipperary, 152.
— —, Tyrone, 151.
— —, U.S.A., Pennsylvania, 149.
— —, Warwickshire, 9, 13, 19, 20, 21, 144, 154.
— —, Whitehaven, 554.
— —, Worcestershire, 15, 16, 19.
— —, Yorkshire, 19, 20, 341.
— —, — and Nottinghamshire, geological suggestions relative to its eastward extension beneath the permian and secondary strata into Lincolnshire, 143.—Discussion, 150.
Coal-formation, transport theory, 585.
Coal-measures, 9, 10, 12, 13, 14, 16, 17, 19, 143, 145, 148, 154.
— —, Clare, 151.
— —, Dover, 543, 544, 548.
— —, Flintshire, 553.
— —, France, 391.
— —, Ireland, 151, 152.
— —, Lancashire, 562.
— —, Limerick, 151.
— —, midland district, 26.
— —, North Staffordshire, 26.
— —, — Wales, 554.

Coal-measures, Nottinghamshire, 339, 340, 341, 342, 343.
— —, Shropshire, 26.
— —, South Africa, 421.
— —, — of England, under secondary rocks, 540.
— —, Warwickshire, 26.
— —, grey middle, 26.
— —, middle, 22, 23, 25, 26, 27, 28.
— —, middle, Ireland, 151.
— —, upper, 22. 23, 24, 25, 26, 27.
— —, —, Ireland, 151.
— —, — red, 23, 24, 26.
— —, — yellow, 23, 26, 27.
— — between Nottingham and Leeds, 18.
— — — Warwickshire and Lancashire coal-fields.—Discussion, 21, 561.
— — lake, France, 425.
Coal-miners, comparative mortality, 243, 244, 253.
Coal-mines, observations on black-damp of, 265.—Discussion, 273.
— —, precautions necessary in use of electricity, 306.—Discussion, 315.
— —, telephonic communications.—Discussion, 124.
Coal-mining, health conditions of, 240.—Discussion, 248.
Coal-screen, Oberegger, 644.
Coal-seams, thinning out of the Silkstone and Beeston, at Acton hall colliery, 162, 233.
— —, Yorkshire, correlation, 163.
Coal-tipplers, modern.—Discussion, 171.
Coal-trough, North Wilts, Oxfordshire, etc., etc., 542.
Coal-tubs, form of, 131, 135, 137, 138.
Coal-washers, Elliott, 55, 56, 58, 59 60, 61.
— —, Murton, 60.
— —, Park collieries, 556, 557.
— —, Francou method, 647.
— —, Nunnery collieries, 80, 81.
— —, Wirral colliery, Neston, Cheshire, 55.—Discussion, 59.
Coalbrookdale, 23.
— coal-field, 24.
Cobalt, South Africa, 432.
Cocknage, pebble-beds 562.
Cochrane, William, *eastern limits of Midland coal-field*, 17, 19.
—, *gold-fields of Matabeleland*, 38.
Cockroaches, not affected by carbon monoxide, 504.
Codsall wood, Chillington, 25.
Coke, G. E., *fencing-gates for winding-shafts*, 158.
—, *how a mine may be dry but not dusty*, 136.
—, quoted, 561.
—, southern limit of Nottinghamshire coal-field, 339.—Discussion, 341.
— *Yorkshire and Nottinghamshire coal-field*, 153.
Coke, analyses, Yorkshire, 61.
Coke, recovery of bye-products in manufacture.—Discussion, 174.
Coke-ovens, Birley Vale, 84.
Colar central gold-mines, India, 359.
— — — —, —, statistics. 367.
— gold-field, India, 357, 360.
— — — —, —, statistics, 366, 367.
— road station, India, 355.
Cole, W. H., *cut-off gear for winding-engines*, 116.
Cole, R. H., *rocket oil-engine*, 171.
Colliery engines, use of expansion gear, 64, 71.
— explosions, Blackwell, Derbyshire, 526, 527.
— —, Brancepeth, 174, 502, 503, 526, 527.
— —, Camerton, Somersetshire, 526.
— —, causes of death, 502.—Discussion, 513, 519, 559.
— —, Haswell, 1844, 220.
— —, Llanerch, 512.
— —, Micklefield, 502, 503, 508, 509, 511, 526, 527.
— —, Quarter, Scotland, 529.
— —, Seaham, 560.
— —, Tylorstown, 502, 503, 508, 509, 527.
— —, some aspects of, 526.—Discussion, 534.
— — and coal-dust, 137, 138.
Collinsville zinc works, Collinsville, Illinois, U.S.A., 375.
Colorado, gold in granite and gneiss, 349.
Colquhoun, A. J., election, N.E., 518.
Columbia river, upper, British Columbia, auriferous gravels, 626.
Colza oil, 104, 108.
Combustible gas in non-fiery mine, 612.
Combustion and air-supply, steam boilers, 322, 333.
— of coal in air, 580.
Commercial travellers, comparative mortality, 244.
Composition and fusibility of coal-ash, 586.
— of black-damp, 272.
— — choke-damp from wells, 265, 267, 268.
— — fire-damp, 611.
— — mine-atmospheres in Donetz coal-field, Russia, 620.
Commern sandstones, Rhenish Prussia, 456.
Committee, election, W.A.B., N.E., 516.
Comparative mortality in different occupations, 244.
Compound pumping-engine, tests, 100, 101.
— winding-engine, 207.—Discussion, 212.
Compressed air, advantages of use, 602.
— —, coal-cutting plant, costs, 499.
— —, — — —, cost of working, 500.
— —, Hickleton main colliery, 315.
— —, haulage, Cannock and Rugeley collieries, 564, 565, 567.
Conductors, 307.

Conglomerate beds, El Boleo, 456.
— —, India, auriferous, 348.
— —, Lake Superior, copper-bearing, 458.
— —, North Wales, 553, 554.
— —, South Africa, 39, 420, 422, 423, 424, 425, 426, 427, 428, 429, 433, 435, 439, 441, 443, 452, 453, 455.
— —, lower cambrian, North Wales, 552.
Coniston series, Lake district, 553.
Connaught, coal-field, 151.
Consolidated Kansas City smelting company, Argentine, Kansas, U.S.A., 376.
Continuous and automatic apparatus for taking samples of air or gas, 619.
Conway vale, North Wales, 553.
Conygre colliery, analysis of gas, 272.
Cooksey, J. H., *underground haulage, Cannock and Rugeley collieries*, 571.
Coorg, India, gold-mining, 346.
Copper, electric-welding, 473.
Copper-bearing conglomerate beds of Lake Superior, 458.
Copper-mines, Sinai, ancient, 598.
— —, Transvaal, 36.
Copper-ores, El Boleo, 456.
— —, North Wales, Llandudno, 553.
— —, South Africa, 432.
Copper pyrites, Huelva, Spain, 451.
— —, India, 351.
— —, South Africa, 428.
Coquillion, J., Coquillion fire-damp indicator, 616.
Coral rag, 270.
Corliss engines, Deptford station, 464, 466.
— valves, 180.
Cornbrash, 270.
Cornish boilers, 237, 324, 326, 331, 332.
— —, Mysore gold-mines, India, 358, 359.
— pumping-engine, 95, 236.
— — —, Nunnery collieries, 80.
— sinking-pumps, Moss Hall coal company, 557.
— valves, 64, 65, 72, 73, 79.
— —, Moss Hall coal company, 558.
Cornwall, miners, comparative mortality, 244.
— united mines, ventilation, 251.
Coromandel gold-mines, India, 359.
— — —, —, statistics, 366, 367.
Correlation of Lanarkshire and southern Ayrshire coal-seams, 89.
Council, election, M., 490.
— —, S., 88.
Council's annual report, M., 486.
— — —, S., 85.
Counter-balance rope, Nunnery collieries, 79.
Counter-balancing of winding-engines, 72.
Coventry, borings, 562.
—, coal-seams, 154.
Cowell, E., election, S.S., 572.
Cowlishaw, W. G., *cut-off gear for winding-engines*, 116.
—, Woodworth cut-off gear for winding-engines, 111. —Discussion, 112.
Crampton, —, quoted, 321, 322.
Crédo deposit of asphalt and petroleum, France, 573.
Crepping hall, 15.
Cretaceous system, 152.
— —, South Africa, 399.
Crœsus gold-mine, South Africa, 440.
Crosby, George, election, M., 117, 485.
Crossland, Alfred, election, M., 227.
Crossness, boring, 543.
Crown reef, South Africa, 394.
— — gold-mine, South Africa, 412, 413, 429, 443, 449.
Crystalline pyrites, South Africa, 439.
— schists, India, Madras, 355.
— —, South Africa, 385.
Culford, Buckinghamshire, boring, 14.
Cumberland, 555.
Cumnock, Ayrshire, coal-seams, 89.
Cupriferous sulphides, Mansfeld, 456.
Currie, Walter, election, N.E., 173.
Cut-off gear for winding-engines, Woodworth progressive, 111.—Discussion, 112.
Cutting and boring, electric, 45.
Cyanide process of gold-extraction, 263.
Cyclopteris, South Africa, 400.
Cyphergat, South Africa, coal-field, 401.

Daggafontein, South Africa, Cassel colliery, 401.
Daglish, John, quoted, 72, 113, 115.
Dakota, South, U.S.A., golden reward mining company, Deadwood, 374.
Dahmenit, 3, 4.
Dalrymple-Hay, —, 482.
Damage caused by industrial establishments in France, responsibility for, 637.
Damaraland, South Africa, 399.
Dampers, expansion, for furnaces of boilers with small water-tubes, 581.
Dangers of blasting in fiery mines, 608.
Darius the Persian, 345.
Darlington, James, *report of proceedings of the explosives committee*, 551.
Darlington, 144.
Daubrée, Prof., quoted, 386.
Davey, H., differential pumping-engine, 236.
—, — — —, tests, 100, 101.
Davies and Lees, quoted, 148.
Davis, Henry, *electricity in coal-mines*, 318.
Davis and Stokes, motor, 319.
Dawes, Messrs, shafts sunk by, 16.
Dawkins, Prof. W. Boyd, quoted, 550.
Dawson, Sir J. W., quoted, 149.
Daykin, George, election, N.E., 518.
De Beers Company, diamond mines, South Africa, fuel, 401.
— — mine, fire at, 93.

De Camp, —, systems of powdered coal-firing, 324, 330.
De Grave, L. W., *electric welding*, 52.
—, *electricity in coal-mines*, 317.
—, quoted. 155.
De Kaap, Transvaal, 378, 399.
De la Beche, Sir H, quotod, 543.
De Lapparent, Prof., quoted, 386.
De Paaz gold-mine, South Africa, 384, 386, 430.
De Rance, C. E., *causes of death in colliery explosions*, 559.
—, depth to productive coal-measures between the Warwickshire and Lancashire coal-fields.—Discussion, 21, 561.
—, notes on the geological features of the coast of North Wales, from Liverpool to Menai bridge, 552.
—, *Nottinghamshire coal-field*, 342.
De Visme Gipps, F. G., election, N.E., 173.
Deacon, Maurice, *blasting efficiency of explosives*, 62.
—, *lead and lap of winding and other engines*, 68.
—, *photography in technology of explosives*, 6.
—, quoted, 64, 65, 319, 320.
Deadwood, South Dakota, U.S.A., golden reward mining company, 374.
Dean Forest, 24.
— — coal-field, 11, 149, 543.
Dearne valley, coal-seams, 162.
Death-rates of various occupations, 243, 244.
Deaths caused by explosions of fire-damp and ignitions of gunpowder, 1873-94, 530, 652.
— in colliery explosions, causes of, 502.—Discussion 513, 519, 559.
— per 1,000 tons raised in coal-mines of United Kingdom, 1855 and 1894, 240.
Dee river, North Wales, 553, 554, 555.
Deflected arc system of welding, 49.
Delagoa bay, railway from Pretoria to Lourenço Marquez, 401.
Delayed ignition of grisounite cartridges, 610.
Denbighshire grits, Silurian, 553.
Deptford station, London electric supply corporation, 462.
Depth to productive coal-measures between the Warwickshire and Lancashire coal-fields.—Discussion, 21, 561.
Derbyshire, 18, 19, 20.
—, Blackwell colliery explosion, 526, 527.
—, coal-analysis, 544.
—, coal-field, 9, 19, 20, 143, 144, 153.
—, comparative mortality, 243, 244.
—, Peak district, use of traction-engines, 284.
Derry, Ireland, 152.
Description of gold-mines of the Transvaal: Witwatersrand, Heidelberg, and Klerksdorp districts, 378.
Desford, Leicestershire, 13.
Deshayes, Victor, spectrum analyses of minerals, 648.
Detaching-hooks, 122, 123.
— —, King, 124.
— —, Ormerod, 123.
Determining calorific values of fuel, 583.
— heating value of coals, 584.
Detonators, 159, 160, 161, 607.
—, percussion, 609.
Devonian system, 14.
— —, South Africa, 379, 383, 384, 398, 399.
Dewsbury, 165.
— moor, Beeston coal-seam, 166.
Dharwars, India, gold-bearing schists, 347.
Diabase, South Africa, 404.
—, amygdaloidal, South Africa, 397, 398, 430.
— dykes, South Africa, 396, 451.
— rocks, India, 350.
Diamond-boring, Shakespear cliff, Dover, section, 544.
— drill, 340.
— mines, South Africa, fuel, 481.
Dickinson, Joseph, *causes of death in colliery explosions*, 523.
—, *Kent coal-field*, 550.
—, quoted, 560.
Diest, Edmund C. van, election, N.E., 518.
Diorite dykes, India, 347.
— rocks, India, 350.
Disengagements of inflammable gas from mines of plastic clay, 613, 614.
Dixon, Prof. H. B., quoted, 169, 537.
Dixon, John, election, N.E., 216.
Dixon, J. S., *Southern Ayrshire coal-fields*, 89.
Dobson, —, quoted, 40.
Dodd, Thomas Robert, election, N.E., 215.
Dolerite dykes, India, 347.
Dolomites, South Africa, 393, 394, 396, 397, 399, 401.
—, — —, Malmani plateau, 399.
Dolomitic limestones, South Africa, 395, 396, 398, 427, 430.
Dominion coal company, 180.
— No. 1 mine, coal-cutting by machinery, 180, 181, 186, 190, 192, 202.
Donald, John Mackintosh, election, N.E., 518.
Doncaster, coal-measures, 154.
Donetz coal-field, Russia, 593, 594.
— — —, —, composition of mine-atmospheres, 620.
Donkin and Kennedy, quoted, 323.
Donkin, Bryan, powdered coal for firing steam-boilers: Wegener and other systems, 321.—Discussion, 332
Doornfontein, South Africa, 381, 394, 408, 409.
Doornkop, South Africa, 430.

Dory, A., occurrence of mercury in Asturias, Spain, 639.
Douglas, Thomas, Brancepeth colliery accident, 174.
—, *causes of death in colliery explosions*, 525.
—, *coal-cutting by machinery*, 204, 206.
—, *Kent coal-field*, 550, 551.
—, *presidential address*, 263.
—, *some aspects of recent colliery explosions*, 534, 535.
—, vote of thanks to owners of works, 555.
—, — — — — mayor of Wigan, 517.
Douglas, Holfontein, South Africa, coal-deposits, 401.
Dover, boring, 540, 548.
—, coal, analysis. 544.
—, coal-measures, 543, 544.
—, Shakespear tunnel, 541.
Dransart, Dr., quoted, 242.
Draper, David, quoted, 382, 383, 387, 389, 392, 393, 395, 397, 427.
Drapers, comparative mortality, 244.
Drilling, Jeffrey borer, 191, 197.
Driefontein, gold-mine, South Africa, 418.
Drighlington, Yorkshire, 164.
Dron, Robert W., Southern Ayrshire coal-fields.—Discussion, 89.
Dubiau water-circulating apparatus, 582.
Dublin, 151.
Duckinfield, use of road locomotives, 283.
Dudley, Uriah, vice-chairman, election, W.A.B., N.E, 516.
Dudley, coal-seams, 149.
—, thick coal-seam, 17, 19.
— castle, 17.
Duerno gold-mines, Spain, 623.
Dunbar estate, India, 350.
Dungannon colliery, Ireland, 151.
Dunlop engine, Moss Hall colliery, 558.
Dunn, Matthias, quoted, 252, 256.
Duplex pumping-engine, tests, 100, 101.
Dupreez reef, South Africa, 384, 408.
Durban, South Africa, railway to Johannesburg, 401.
Durban-Roodepoort gold-mine, South Africa, 391, 410, 411, 449.
Durham, comparative mortality, 243, 244.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, explosions of fire-damp or coal-dust, 528, 651, 652.
—, south, hydrogen from salt borings, 274.
—, under sea coal, 149.
Durie colliery, pumping-engine tests, 100, 101.
Durnford, H. St. John, member of council, election, M., 490.
—, notes on the sinking of No. 1 pit at Acton Hall colliery, with special reference to the thinning out of the Silkstone and Beeston coal-seams.—Discussion, 162, 233
Dust, samples, Cinderhill colliery. 135.
— and metallic fumes, interception of, 619.
Dust-coal for firing steam-boilers, 321.
Dust-firing in brown coal briquette-works, 574.
Duty of pumping-engines, 94.—Discussion, 235.
Dwyka conglomerates, South Africa, 400.
Dykes, India, dioritic, 347.
—, South Africa, 414, 416, 418, 419, 429, 451, 453.
—, — —, granite, 382, 390.
—, — —, greenstone, 380.
Dynamite, 218.
Dynamos, Immisch, 81.

Eagle hill, South Africa, 397.
Eagles reef, South Africa, 430.
Earthenware manufacturers, comparative mortality, 243, 244.
East highlands, Ireland, 147.
— London, South Africa, railway to Springfontein, 401.
— rand gold-mines, South Africa, 413, 418, 419, 429, 455.
Eastern counties coal-boring association, 15, 20.
— limits of the Midland coal-field, 9.—Discussion, 17.
— rand, South Africa, 417, 422.
Eastleigh gold-mine, South Africa, 396, 430, 432.
Eastward extension of the Yorkshire and Nottinghamshire coal-field, beneath the permian and secondary strata into Lincolnshire, 143.—Discussion, 150.
Eastwick, W., quoted, 345.
Eckington, Derbyshire, 343.
Ede, Henry Edward, election, N.E., 518.
Edwalton, Nottinghamshire, borehole, 339, 340, 341.
Efficiency of a locomotive with separate steam and exhaust valves, 637.
— — explosives.—Discussion, 62.
El Boleo, conglomerates, 456.
Elandsfontein, South Africa, 381.
Electric bell signals, Wearmouth colliery, 225.
— coal-cutting plant, cost, 499.
— — — —, cost of working, 500.
— — — on longwall-faces, 492.—Discussion, 501.
— haulage, Cannock and Rugeley collieries, 564, 565.
— lighting, Birley collieries, 82, 84.
— locomotives, 479.
— machinery, mining, 257.
— — for mines.—Discussion, 125, 228.
— motors, 293.
— plant, Nunnery collieries, 80.
— power-transmission in mines, 599, 600, 601.

Electric signalling, India, Nundydroog gold-mine, 359.
— —, Cannock and Rugeley collieries, 571.
Electric Supply Corporation, Deptford station, 462.
Electric-welding, 40; Benados or arc system, 41; deflected arc system, 49.—Discussion, 52, 230.
— —, Jessop and Sons, 76.
Electric-welding Company, London, 472.
Electricity in coal-mines, precautions necessary, 306.—Discussion, 315.
Ellam, Albert Spencer, election, N.E., 174.
Elliott, coal washer, 55, 56, 58, 59, 60, 61.
—, locked-coil ropes, 558.
Elliptical roasting-furnace, dimensions, etc., 377.
Elsburg reef, South Africa, 384, 386, 389, 395, 406, 430.
Elves, Edward, election, N.E., 216.
Elwen, — quoted, 271.
Enclosed electric-motors, 313.
Endless-rope haulage, Cannock and Rugeley collieries, 564, 565, 566, 568, 569, 570, 571.
— — —, Nunnery collieries, 79, 80.
— — —, Roland colliery, Rhenish Prussia, 633.
Endon, pebble beds, 562.
Engine and boiler testing, 236.
Engines, Birley collieries, 82, 83, 84.
—, lead and lap of, 64.—Discussion, 68, 233.
—, Nunnery collieries, 79, 80.
—, pumping, duty of, 94.
—, Willans and Robinson, 81.
Engine-planes, Wearmouth colliery, 221, 223.
English coal compared with South African, 401.
Enville, 22, 23.
Eocene period, Ireland, 152.
Erewash valley, 153.
Erythroe, Hercules temple, 346.
Essex, south, coal-trough, 542.
Etheridge, —, quoted, 14.
European labour, cost in Indian gold-mines, 362, 364.
Eustice, George William, election, N.E., 173.
Evans Cornish sinking-pumps, Moss Hall coal company, 557.
Expansion and counter-balancing of winding-engines, 72,
Expansion-dampers for furnaces of boilers with small water-tubes, 581.
Expansion-gear, 64, 71.
— —, winding-engines, 604
Experiments, electric-welded bars, 48.
—, frue-vanners, 645.
—, hand-welding, 49.
Experiments, powdered coal for firing steam-boilers, 321-338.
—, timber, 90.
Exploring respirators, Forster and Fleuss, 560.
Explosion of coal-dust, notes on, 536.—Discussion, 539.
Explosions, Blackwell colliery, Derbyshire, 526, 527.
—, Brancepeth colliery, 174, 502, 503, 526, 527.
—, Camerton colliery, Somersetshire, 526.
—, Karwin colliery, Hohenegger shaft, 605.
—, Llanerch colliery, 512.
—, Micklefield colliery, 502, 503, 508, 509, 511, 526, 527.
—, Quarter colliery, Scotland, 529.
—, Seaham colliery, 560.
—, Tylorstown colliery, 502, 503, 508, 509, 527.
—, some aspects of colliery, 526.—Discussion, 534.
— of fire-damp, 252.
— — — — and ignitions of gunpowder, deaths from, 530.
— — — — or coal-dust, 1895, 528, 651, 652.
Explosives antigrisou, 3.
—, ardeer powder, 166, 167, 168.
—, bellite, 167.
—, blasting efficiency.—Discussion, 62.
—, blasting-gelatine, 3.
—, blasting-powder, 6, 8, 167, 169, 218, 219, 274, 527, 533, 537.
—, British made, 167.
—, carbonite, 3, 166, 167, 168.
—, cost, India, 353, 364.
—, dahmenit, 3, 4.
—, detonators, 607.
—, dynamite. 218.
—, gelatine-dynamit, 4, 5.
—, gelatine-dynamit I., 3, 4, 5.
—, gelatine-dynamit II., 3.
—, gelatinous-cartridge, 168.
—, German made, 167.
—, grisoutine, 3, 5.
—, grisoutit, 3.
—, guhr-dynamit, 3, 4.
—, gun-cotton, 3.
—, gunpowder, 169, 527, 533, 537.
—, hellhoffit, 3.
—, kohlen-carbonite, 67.
—, mining.—Discussion, 121, 166.
—, moss-tamping, 4.
—, nitrate of ammonium, 5.
—, nitro-glycerine, 3.
—, nitro-starch, 3.
—, photography in the technology of, 2.—Discussion, 6.
—, progressit, 3, 4, 5.
—, roburit, 3, 4, 5.
—, Roth method of firing shots, 162.
—, Sprengel, 538.

Explosives, water-cartridges, 4, 6, 168.
—, westfalit, 3, 4.
—, wetter-dynamite, 3, 4, 5, 167.
— committee, report of proceedings.—Discussion, 175, 218, 551.

FAIRLEY, T., quoted, 269, 276.
Fan-engine, Seghill, 71, 74.
Fan ventilation, 252.
Fans, Capell, 8'.
—, Guibal, 80.
—, Park collieries, 556.
—, Struvé, 252.
—, Waddle, 67, 83, 84.
—, Walker, 80, 84, 556.
FARADAY AND LYELL, quoted, 220.
Farmers, comparative mortality, 244, 253.
Farnley iron, 47, 480.
FARR, DR., quoted, 243.
Fatal accidents in coal mines, United Kingdom, 1855 and 1894, 240.
FAULDS, ALEXANDER, member of council, election, S., 88.
— *treatment of timber for use in mines*, 91.
Faults, South Africa, 414, 416, 418, 419.
—, Symon, 25.
FAVELL, T. M., *cut-off gear for winding-engines*, 113, 114.
—, *lead and lap of winding and other engines*, 69.
Favularia, South Africa, 401.
FAWCETT, semi-plastic machines, 81.
FELDTMANN, W. R., gold-metallurgy on the Witwatersrand, S.A.R., 525.
FELLOWS, ALFRED, election, N.E., 215.
Felsite, Buckinghamshire, 14.
Fencing-gates for winding-shafts.—Discussion, 156.
FERGUSON, C. A., election, N.E., 518.
FERRANTI dynamos, etc., Deptford station, 463, 464, 465, 466, 467, 471.
Ferreira gold-mine, South Africa, 400, 406, 412, 413, 414, 415, 449, 451.
Ferruginous quartzite, South Africa, 382.
— rocks, India, gold-bearing, 347.
— —, South Africa, 379, 381, 383, 394, 398, 399.
Fiery and dusty mines, 219, 220.
— mines, dangers of blasting, 608.
Fifeshire, fire at Capeldrae colliery, 92.
—, Beath, phthisis, 245.
FIGARI, ALBERTO, election, N.E., 173.
File-makers, comparative mortality, 243, 244.
FINCH, WILLIAM WESLEY, election, C., 127.
Fire at Kleophas colliery, Upper Silesia, 618.
Fire-damp, 5, 275, 278, 510, 536.
— —, composition, 611.
— —, explosions, 252.
— —, —, 1895, 528, 529, 651, 652.
Fire-damp and coal-dust, 219.
— — — ignitions of gunpowder, de from, 530.
— — indicators, Coquillion, 616.
— — —, Hardy, 617.
Firing shots, Roth method.—Discus 159.
— with coal-dust in brown-coal briqu works, 574.
— steam-boilers, powdered coal: Weg and other systems, 321.—Discus 332.
Firth college, Sheffield, 77.
— —, —, vote of thanks to the authori 75.
Fishermen, comparative mortality, 2
Fissure-veins, Matabeleland, 32, 34.
Flameless explosives committee, re of proceedings.—Discussion, 175, 551.
Flashing-point, Russian petroleum, 108.
FLEMING, JOHN, election, S., 235.
FLEUSS, —, apparatus for breathing n ous gases, 560.
—, diving dress, 559.
FLEUSS AND FORSTER, exploring resp tor, 560.
Flintshire, middle coal-measures, 553
—, west, coal-field, 144.
Float quartz, India, 351.
Flockton, coal-seam, 163, 164, 165.
Folkstone, palæozoic fault, 543.
Fonteins, South Africa, 381.
Forest of Dean, coal-field, 11, 24, 543.
— — Wyre, coal-field, 22, 23, 24, 25.
FORGIE, J. T., quoted, 235.
—, *Southern Ayrshire coal-fields*, 90.
—, *treatment of timber for use in m* 91.
—, vice-president, election, S., 88.
FORSTER AND FLEUSS, exploring resp tor, 560.
Forth, coal-field, 144.
FOULSTONE, HERBERT, election, M.,
FOWLER, GEORGE, how a mine may dry but not dusty, 128; appendix, —Discussion, 136.
FOWLER, JOHN, quoted, 291, 295.
FOWLER & Co., Leeds, winding-engi 207.
France, central plateau, granite, 380
—, coal-measures, 391.
—, — — lakes, 425.
—, Crédo deposit of asphalt and pe leum, 573.
—, granites, etc., 383.
—, length of stemming, 219, 220.
—, mine owned and worked by min 636.
—, palæozoic fault, 543.
—, primary rocks, 385.
—, responsibility for damage caused industrial establishments, 637.

France, sinking shafts by freezing, 297.
—, southern portion of Valenciennes coal-field, 589.
Francis, South Africa, 400.
FRANCOU method of coal-washing, 647.
Freezing process of shaft-sinking, Gobert, 297.—Discussion, 304.
Freights, Matabeleland, 30.
French and India, 346.
FRIEDEBERG system of powdered coal-firing, 324, 328, 329, 330.
Frue-vanners, experiments, 645.
Fuchs colliery, Lower Silesia, haulage installation, 631.
Fuel, determining calorific value, 583.
—, India gold-mines, costs, 364.
—, oxidizing of ores, 375.
Fumes, metallic, interception of, 619.
Furnace gases, analysis, 322, 326, 332.
— ventilation, 251.
— —, Wearmouth colliery, 226.
Furnaces, ore-calcining, 369, 370, 371, 372, 373, 374, 375, 376, 377.
—, coal-dust, 575.
— of boilers with small water-tubes, expansion-damper, 581.
Fusibility and composition of coal-ash, 586.

Gaberones, Matabeleland, 460.
GALBRAITH, W. R., 482.
Galena, South Africa, 397, 440, 453.
GALLOWAY, W., compound winding-engine, 207. –Discussion, 212.
—, quoted, 507, 536.
GALLOWAY tubes, 359.
Galway, Ireland, 151.
Gardeners, comparative mortality, 244, 253.
GARDON, —, axle-box for mine tubs, 633.
GARFORTH, W. E., member of council, election, 490.
—, *treatment of timber for use in mines*, 231, 233.
Garforth collieries, detaching-hooks, 123.
GARLAND, J., quoted, 357.
Garland shaft, Champion reef gold mine, India, 361.
Gas, combustible, in non-fiery mines, 612.
—, inflammable, from mines of plastic clay, 613, 614.
—, suffocative, met with in wells; nature and sources of, together with further observations on the black-damp of coal mines, 265.—Discussion, 273.
— and petroleum motors, 602.
— — smoke-mask, Müller, 248, 483.
— or air, continuous and automatic apparatus for taking samples of, 619.
Gaseous poisoning, alcohol in reference to, 275.
Gases from boiler-furnaces, analyses, 322, 326, 332.
Gatsrand series, South Africa, 379, 395, 396, 398, 399.
Gault, Dover, 544.
—, Suffolk, 15.
Gaya temple, India, 345.
GEDDES, CHARLES D., election, S., 235.
Geduld, South Africa, 392.
GEINITZ, DR., quoted, 562.
Gelatine-dynamit, 4, 5.
Gelatine-dynamit, I., 3, 4, 5.
Gelatine-dynamit, II., 3.
Gelatinous-cartridge, 168.
Geldenhuis gold mine, South Africa, 412, 418, 444, 449.
— valley gold mine, South Africa, 381, 386, 394, 406, 408, 409.
Geological description of the gold-mines of the Transvaal (Witwatersrand, Heidelberg, and Klerksdorp districts), 378.—A. General geology of the area, 379.—B. Special study of the Witwatersrand gold-bearing series, 402.—C. Special description of the gold ores of the Witwatersrand, 433.—D. Gold-tenour of the ore, its variations according to the strike and dip of the beds (deep levels), 442.—E. Origin and mode of formation of the Witwatersrand auriferous districts, 452.
— features of the coast of North Wales from Liverpool to Menai bridge, 552.
— suggestions relative to the eastward extension of the Yorkshire and Nottinghamshire coal-field beneath the permian and secondary strata into Lincolnshire, 143.—Discussion, 150.
Geology of the Bayer shaft and adjacent portion of the Pilsen coal-basin, Bohemia, 590.
George and May gold-mines, South Africa, 410, 449.
George Goch gold-mine, South Africa, 412, 449.
Germania adit, Matabeleland, 33.
— reef, Matabeleland, 37.
Germany, competition in iron and coal, 260.
—, foreign explosives, 167.
—, railway rates, 261.
—, Rothe-todte-liegende series, 26,
GERNET, A. VON, present method of declaring the monthly output of gold of Witwatersrand district, with a suggestion for its alteration, 624.
GERRARD, JOHN, *causes of death in colliery explosions*, 514, 519.
Ghauts, India, gold-mining, 346, 347.
GHAZNI, MAHOMED, 345.
GIFFARD, G. GRAVES, vice-chairman, election, W.A.B., N E., 516.
Giggleswick, Lancashire, 343.
Gilbert, shaft, Mysore gold-mine, India, 361, 366.
GILCHRIST, JAMES, member of council, election, S., 88.

GILL, WILLIAM, election, N.E., 215.
Gins for winding, 254.
Ginsberg gold-mines, South Africa, 449.
GIPPS, F. G. DE VISME, election, N.E., 173.
Glossopteris augustifolia, Brongt., South Africa, 400.
— communis Feistm., South Africa, 400.
Glasgow, barometer, thermometer, etc., readings, 1895, 651.
— to Bombay, freights, 261.
Glencairn gold-mines, South Africa, 449.
Gloucestershire, 19.
—, Redwick, accident from gas in well, 265, 266, 270, 276.
Gneiss, India, gold-bearing, 347, 350, 352.
—, South Africa, 379, 380, 382, 392, 435.
Gneissic rocks, Africa, 349.
Gob-material, balance with water-brake for lowering, 634.
GOBERT, A., freezing process of shaft-sinking, 297; old process, 297.—Internal and external pressure, 297.—Drawbacks of an excessive internal pressure, 298.—Principle of low internal pressure, 298.—Evaporation of ammonia in freezing tube, 298.—Serpentine injector, 299.—Method of regulating the process of freezing, 300. — Case of constant pressure, 300.—Verticality of freezing-tubes, 301.—Excess of ammonia, 301.—Signs by which admission of liquid in excess will be recognized, 302.—Ammonia mist, 302,—Lowering of the temperature of compressor, 302.—Ease with which the working of engine can be regulated, 302.—Explanation of figures, 302.—Conclusions, 303.—Discussion, 304.
GODWIN-AUSTEN, —, quoted, 148, 540, 550.
Gold, granite and gneiss, 349.
—, India, Mysore, Colar gold-field, production, 366, 367.
—, —, production, 365.
—, metallurgy, Witwatersrand, Transvaal, 625.
—, present method of declaring the monthly output, of the Witwatersrand district, with a suggestion for its alteration, 624.
Gold-bearing hæmatites, Brazil, 383.
— — rocks, Africa, 348, 402.
— — —, India, 347.
— — —, South Africa, Witwatersrand, 402.
Gold extraction, Cassell-Hinman bromine process, 622.
— —, cyanide of potassium process, 263, 623.
Gold-dust, as money, India, 345, 346.
Gold-fields, India, 345.
— —, —, Madras, 355.
— —, —, Mysore, 359.
— —, Matabeleland, 29.—Discussion, 38, 460.
Gold-mines, India, 346, 357, 358.
— —, Spain, Duerno, 623.
— —, Transvaal, Witwatersrand, Heidelberg and Klerksdorp districts, 378.
Gold-mining, New Zealand, 263.
— —, South Africa, 263
— —, Western Australia, 628.
— — companies, India, 357.
Gold-ores, refractory, of Queensland, th sources and treatment, 631.
— —, Transvaal, Witwatersrand, spec description, 433.
— —, North Wales, 553.
Golden reward mining company, De wood, South Dakota, U.S.A., 374.
GOLDMANN, C. S., quoted, 282, 387, 3 400, 401, 427, 455.
Goldthorn hill, sinking and boring, 25
Gondwánas, India, 400.
GOODLAND, GILLMORE, election, N. 518.
Gosford, waterworks, 25.
GOUTAL, E., determining calorific va of fuel, 583.
Gradients for road-engines, 293, 295.
Grange, North Wales, 554.
Gramme-wound armatures, 312, 313.
Granite, India, Madras, 350, 355, 356
—, Matabeland, 32.
—, South Africa, 32, 349, 379, 380, 3 383, 385, 392, 393, 394, 397, 435.
— dykes, South Africa, 382, 390.
GRANITE QUARRY COMPANY, Leicest traction-engines, 286.
Granite veins, North Wales, 552.
Granitic hummocks, South Africa, 38
GRANT, A. M., *duty of pumping-engin* 238, 239.
—, member of council, election, S., 88.
GRANT, JAMES, quoted, 252.
Granulites, South Africa, 380, 385, 43.
GRAVE, L. W. DE, *electric welding*, 52.
—, *electricity in coal-mines*, 317.
—, quoted, 155.
Gravels, auriferous, British Columb Upper Columbia river, 626.
GRAVES, H. G., *suffocative gas met w in wells*, 275.
Great Barr, Hamstead colliery, 562.
Great fall, Shakespear cliff, Kent, bori 540, 544.
Great Fenton colliery, analysis of g 272.
Great Ormes head, North Wales, 553.
GREATHEAD, J. H., 482.
—, tunnelling shields, 477.
GREAVES, J. O., *notes on the sinking No. 1 pit, at Acton Hall colliery*, 233
Greeks, India, 346.
GREEN, PROF., 269.
GREEN economizers, Deptford statio 464.
— —, Park collieries. 557.
Greenlane, coal-seam, 163, 165.
Greenstone dykes, South Africa, 380.

Greenstone-porphyry, India, 350.
GRESLEY, W. S., Yorkshire and Nottinghamshire coal-field: geological suggestions relative to its eastward extension beneath the permian and secondary strata into Lincolnshire, 143. —Discussion, 150.
GREY, FREDERICK WILLIAM, election, N.E., 518.
Grey chalk, Dover, 544.
— gneiss, India, 350.
— middle coal-measures, 26.
GRIFFITH, N. R., quoted, 297.
GRIFFITH, N. R., G. P. SIMPSON AND F. BRADY, Kent coal-field, 540.—Discussion, 550.
GRIFFITHS, ROBERT, quoted, 254.
Griqualand, west, South Africa, 399.
Grisounite cartridges, delayed ignitions, 610.
Grisoutine, 3, 5.
Grisoutit, 3.
Grocers, comparative mortality, 244.
GRUNDY, JAMES, election, N.E., 215.
Guanda district, Matabeleland, 37, 460.
Guhr-dynamit, 3, 4.
GUIBAL fan, 80.
Guides in shafts, 254.
Gun-cotton, 3.
Gun-powder, 169, 527, 533, 537, 538.
— —, deaths from ignitions, 530.
GUTHRIE, C. J., AND J. M. RONALDSON, quoted, 529.

HAARMANN, C., quoted, 134.
Hadiabetta hills, India, 349, 350.
Hæmatites, gold-bearing, Brazil, 383.
—, North Wales, 553.
—, South Africa, 383, 432.
HAGGIE, PETER SINCLAIR, election, M., 485.
Haigh Moor, coal-seam, 164, 165.
HALDANE, DR. JOHN S., quoted, 248.
—, causes of death in colliery explosions, 502.—Discussion, 513, 519, 559.
—, investigation on the nature and sources of suffocative gas met with in wells; together with further observations on the black-damp of coal-mines, 265.—Discussion, 273.
—, prize for paper, 1.
Halesowen, shafts sunk near, 16, 22.
Halfway house, South Africa, 382.
HALL, HENRY, quoted, 167, 507, 536, 538.
—, some aspects of recent colliery explosions, 526.—Discussion, 534.
—, ventilation-recorder, Park collieries, 556.
HALL, JOHN, quoted, 259.
HALL, M., member of council, M., 490.
HALL, WILLIAM, election, S.S., 563.
HALLIDAY, JOHN, election, S., 235.
HALSE, EDWARD, hon. sec. W.A.B., N.E., 515, 516.
Hamburg, manufacture of steel barrels, 51.
HAMILTON, JAMES, member of council, election, S., 88.
Hamilton, 240.
Hamstead colliery, 17, 22, 562.
Hand-stoking, 332.
Hand-welding, experiments, 49.
Harcott, coal-seams, 22.
Harden wood, Matabeleland, 30.
HARDIE, JAMES, member of council, election, S., 88.
HARDWICK, PROF. F. W., member of council, election, M., 490.
HARDY, M. E., fire-damp indicator, 617.
HARGREAVES, T. SIDNEY, election, N.E., 174.
HARGREAVES, WILLIAM, *methods of closing the tops of upcast winding shafts*, 122, 123, 124.
HARGREAVES, WILLIAM ARTHUR, election, M., 485.
HARRISON, J. W., election, N.E., 216.
HARRISON, STEPHEN, election, M., 117.
HARRISON, coal-cutting machine, 186, 192, 193, 194.
HARROP, WILFRED MARSHALL, election, M., 485.
Hartebeestfontein, South Africa, 382, 427.
Hartshill stone, Warwickshire, 12, 13.
HARVEY, FRANCIS G., election, N.E., 518.
Harwich, chalk, 15.
—, coal-measures, 154.
HASSAM, A., *cut-off gear for winding-engines*, 115.
—, quoted, 271.
HASTIE, JAMES, *Southern Ayrshire coal-fields*, 90.
—, *treatment of timber for use in mines*, 93.
—, vice-president, election, S., 88.
Hastings beds, 270.
Haswell colliery, explosion, 1844, 220.
HATCH AND CHALMERS, quoted, 395.
HATHORN-DAVEY AND CO., pumping-engine, 236.
—, — —, Moss Hall coal company, 557.
Haulage, 253.
—, endless-rope, Roland colliery, Rhenish Prussia, 633.
—, Fuchs colliery, Lower Silesia, 631.
—, Nunnery collieries, 79, 81.
—, Cannock and Rugeley collieries, 564.
—, Wearmouth colliery, 221.
Hauling-engines, 65, 66, 70.
— —, Birley collieries, 82, 83, 84.
— —, Park collieries, 556.
— —, Wearmouth colliery, 223, 224.
Haunchwood colliery, 19.
Hawkers, comparative mortality, 244.
HAY, WILLIAM, fencing-gates for winding-shafts.—Discussion, 156.

HAYWARD, W. J., member of council, election, 572.
HEAD, JEREMIAH, *road locomotives*, 291.
—, *suffocative gas met with in wells*, 275.
Headington, analysis of gas from well, 268, 269.
HEADLEY, WALTER EDWARD, election, M., 117.
Health conditions of coal-mining, 240.—Discussion, 248.
Heat transmission, firing steam-boilers, 322.
HEATH, JOHN, *lead and lap of winding and other engines*, 72.
—, *use of petroleum in safety-lamps*, 109.
HEATH, WM., *causes of death in colliery explosions*, 561.
— *cut-off gear for winding-engines*, 114, 115, 116.
— *use of petroleum in safety-lamps*, 110.
HEATH AND FROST, oil-burner, 105, 106, 107, 108, 109.
—, gelatinous cartridge, 168.
HEATH AND WOODWORTH, coal-tippler, 171, 172.
Heating value of coals, calorimeter for determining, 584.
Hebburn, experiments with explosives, 217.
Hecla mine, Lake Superior, copper-bearing conglomerates, 458.
HEDLEY, JOHN, quoted, 252.
HEDLEY, J. L., *causes of death in colliery explosions*, 521.
—, presentation to A. C. Kayll, 217.
Heidelberg, South Africa, 382, 391, 392, 393.
—, — —, description of gold-mines, 378.
—, — —, gold-bearing beds, 462.
— gold-mine, South Africa, 419, 423, 426.
Hellhoffit, 3.
Hempshall, upcast pit, samples of dust, 135.
Henry Nourse gold-mine, South Africa, 391, 412, 417, 449.
HEPPLEWHITE, W. H., quoted, 155.
Herbert gold-fields, South Africa, 397.
Hercules temple, Erythroe, 346.
Hertfordshire, coal-trough, 542.
HEWITT, H. R., *Yorkshire and Nottinghamshire coal-field*, 153.
Heysham point, Lancashire, 554.
Hickleton main colliery, 315.
HICKMAN, SIR ALFRED, Haunchwood colliery, 19.
HICKS, DR., quoted, 552.
Highfield, Nottinghamshire, bore-hole, 339, 340.
Highgate common, boring, 25.
Highley, coal-seams, 22, 23.
— colliery, near Kiulet, 23.
Himalayan districts, India, gold-dust as money, 346.
Himley park, boring, 25.
Hinckley, Warwickshire, 13.
Hindu scriptures, gold-dust, 346.
Hirdre-faig, North Wales, 554.
HIRT, DR., quoted, 245.
HOBSON, JOHN, election, M., 227.
HOBSON, J. B., election, N.E., 173.
Hockley Hall colliery, sinking, 19.
HOFFMANN, CHARLES, election, N.E., 216.
HOFFMAN, brick-kiln, 81.
Hohenegger shaft, Karwin, 605.
HOHO-LEGRANGE, system of electric-welding, 40.
Holfontein colliery, South Africa, 400, 401.
HOLIDAY, R., scrutineer, M., 485.
Homalonotus Herschelli, South Africa, 383.
HOOSON, THOMAS, quoted, 275.
Horn picks, India, 346.
Hornblendic rocks, India, 350, 358.
Horncastle, secondary rocks, 148.
Horse-gins, 254.
Horse-shoe calcining furnace, dimensions, etc., 377.
Hospital hill, South Africa, 381, 419.
— —, — —, clay slates, etc., 398, 399.
— —, — —, ferruginous shales, 383, 390.
Houghton main colliery, detaching-hooks 124.
Houillères de Saint-Étienne, Société anonyme des, Treuil collieries, 213.
HOUSE, JOHN, election, N.E., 216.
Houten estate, South Africa, 380.
How a mine may be dry but not dusty, 128.—Discussion, 136.
HOWLEM AND CO., JOHN, 482.
Huelva, Spain, copper pyrites, 451.
—, —, iron pyrites, 383, 451.
HUGHES, H. W., quoted, 17.
HUGHES, PROF. MCKENNY, quoted, 552.
HULL, PROF. EDWARD, *depth of productive coal-measures between the Warwickshire and Lancashire coal-fields*, 21, 25.
—, eastern limits of the Midland coal-field, 9.—Discussion, 17.
—, presidential address, 263.
—, quoted, 11, 12, 22, 23, 26, 27, 144, 148, 153, 154, 342, 343, 344, 561.
HUMBERT, —, disengagement of inflammable gas from mines of plastic clay, 614.
Hungarian mining and geological millennial congress, Budapest, 1896, 88.
HUNT, DOUGLAS, process of copper extraction, 376.
Huntington, sinkings, 24, 303, 305.
HUTCHINSON, R. L., election, N.E., 216.
HUTTON AND SONS, Sheffield, 77.
Hyaline quartz, South Africa, 385.
Hydraulic pumps, Moore, 236.
Hydrochloric acid 159.
Hydrogen in borings for salt, South Durham, 274.
Hydrogen-lamp, Clowes, 273.

Ibstock colliery, Leicestershire, 13.
Ignition, delayed, of grisounite cartridges, 610.
Ignitions of gunpowder, deaths from, 530.
Illinois, U.S.A., coal cutting by machinery, 258.
—, —, Collinsville zinc works, 375.
Illuminants used in mines, photometric values.—Discussion, 155.
Immisch, dynamos, 81.
Inclines, self-acting, brake and pulley, 634.
India, lower gondwánas, 400.
—, phallic religion, 36.
Indian consolidated company, 360.
— gold-fields, 345.—Introduction, 345.—Wynaad district, 349.—Madras gold-field, 355.—Working details of several representative gold-mines, 357.—Tables, I.-IX., 361-368.
— gold-mines estate, India, 349.
Indicating pumping-engines, 95, 101.
Indicator, McKinnel and Buchanan, 102.
— diagrams, 111, 113, 115, 209, 210, 211, 212, 214, 236, 238, 239.
Industrial establishments in France, responsibility for damage caused by, 637.
Indwe, South Africa, coal-field, 401.
Inflammable gas, mines of plastic clay, 613, 614.
Infra-lias formation, South Africa, 379.
Ingersoll Rock-drill Company, 180.
—, air-compressor, 81.
Ingersoll-Sergeant, coal-cutting machine, 185, 192, 193, 204.
Ingram, Arthur Edgar, election, S., 88.
Injector, sepentine, 298.
Innkeepers, comparative mortality, 244.
Inspectors of mines, influence of, 249, 250.
Institution of Civil Engineers, vote of thanks to, 461.
Interception of dust and metallic fumes, 619.
Investigation on the nature and sources of suffocative gas met with in wells: together with further observations on the black-damp of coal-mines, 265.—Discussion, 273.
Ireland, carboniferous era, 150, 151, 152.
—, coal-fields, 144, 155.
—, coal-measures, 151, 152.
—, east highlands, 147.
—, west highlands, 147.
Irish sea, 146, 147, 552, 553, 554.
Iron, electric-welding, 473.
—, Farnley, 47, 48.
—, India, cost, 353, 364.
—, Low moor, 47, 48, 49.
—, Netherton crown best, 48, 49.
Iron-ores, Matabeleland, 30.
— —, North Wales, hæmatite, 553.
Iron-ores, roasting, 635.
— —, South Africa, 30, 383.
— —, — —, hæmatite, 432.
Iron-pyrites, India, 351.
— —, South Africa, 380, 383, 404, 435, 436, 437, 438, 439, 440, 453.
— —, Spain, Huelva, 383, 451.
Ironstone districts, comparative mortality of miners, 244.
— mines, Cleveland, carbonic acid gas, 274.
Ironstones, black-band, 26.
Iron-wire winding ropes, 255.
Ironworks, Broad Oaks, 84.
Isle of Man, 146, 552, 555.

Jackson, Douglas, member of council, election, S., 88.
Jackson, John, *how a mine may be dry but not dusty*, 136.
Jameson, John, recovery of bye-products in the manufacture of hard coke.—Discussion, 174.
Jeaffreson, Dr., quoted, 242.
Jeffrey, boring-machine, 191, 197.
Jenkins, John Partridge, election, M., 227.
Jessop and Sons, Brightside, Sheffield, 76.
Jigging-screens, Wood and Burnett, 80.
Jobling, John William, election, N.E., 216.
Johannesburg, South Africa, 378, 380, 381, 382, 383, 391, 392, 393, 395, 396, 400, 407, 408, 412, 425, 429.
—, — —, Chamber of Mines, 447.
—, — —, coal-beds, 401.
—, — —, Karoo series, 398, 400.
—, — —, Premier gold-mine, 449.
—, — —, railway to Cape Town, 401.
—, — —, — — Durban, 401.
Johnson, Algernon Edward, election, N.E., 173.
Johnson, G. H., election, S.S., 572.
Johnson, Henry, quoted, 16.
Johnson, Clapham, and Morris, oil-burner, 105, 106, 107.
Jones, Daniel, *depth of productive coal-measures between the Warwickshire and Lancashire coal-fields*, 23.
—, quoted, 22, 25, 26.
Jordan, S., roasting iron and manganese ores, 635.
Jubilee gold-mine, South Africa, 412, 416, 417, 448, 449.
— reef, South Africa, 394.
Jukes, Prof. J. B., quoted, 11, 16.
Jukes furnaces, Wearmouth colliery, 225.
Jumpers gold-mine, South Africa, 402, 436, 449.
Junction boxes, 309.

Kaap range, South Africa, 399.
Kaffirkraal, South Africa, 397.

Kangundy gold-mines, Mysore, India, statistics, 366.
Kansas city smelting company, Argentine, Kansas, U.S.A., 376.
Karoo, South Africa, carboniferous deposits, 379.
— formation, South Africa, 379, 392, 398, 399, 400, 401, 418, 421.
Karwin, explosion at the Hohenegger shaft, 605.
Kashmir, India, gold-mines, 346.
Kaspatyrus, Kashmir, India, gold-mines, 346.
KATZER, DR. FR., anthracite in the permian rocks of Bohemia, Austria, 587.
KAYE, oil-burner, 105, 106.
KAYLL, A. C., presentation to, N.E., 217.
—, *report of the proceedings of the explosives committee*, 551.
KEBLER, JULIAN A., election, N.E., 216.
Kieselguhr, 167.
KELVIN, LORD, quoted, 256.
Kempinkote gold-mines, Mysore, India, statistics, 360, 367.
KENNEDY, DR. A. B. W., quoted, 474.
KENNEDY, RANKIN, *electric welding*, 230, 231.
—, electrical machinery for mines.—Discussion, 125, 228.
Kennedy shaft Nundydroog gold-mine, India, 361.
Kent coal-field, 144, 540.—Discussion, 550.
— coal-fields syndicate, 544.
Keuper building-stones, Cheshire, 27.
— formation, Lancashire, etc., 27.
— —, Warwickshire, 562.
— marl, Mendip hills, 562.
Kew, barometer, thermometer, etc., readings, 1895, 651.
Kilkenny, coal-field, 554.
Kilwinning, Ayrshire, coal-seams, 89, 90.
Kimberley, South Africa, 30, 393, 397.
— reef, South Africa, 384, 386, 387, 389, 395, 406, 419, 421, 423, 426, 427, 429, 433.
Kimmeridge clay, 270.
KIND-CHAUDRON process of sinking, 304, 305.
Kinlet, Highley colliery, 23.
KING, DAVID, 345.
KING'S detaching-hook, 124.
King's county, pipe clays, 153.
King's Lynn, 343.
KINNAHAN, G. H., *Yorkshire and Nottinghamshire coal-field*, 150.
Kirby, west, 554.
KIRCHNER, L., ore-concentrators, 640.
KIRKUP, FREDERICK O., election, N.E., 174.
Kleinfontein deep gold-mine, South Africa, 422.
— gold-mine, South Africa, 418, 419, 424.
Kleophas colliery, Upper Silesia, fire at, 618.
Klerksdorp, South Africa, 390, 391, 393, 426.
—, — —, geological description of gold-mines, 378.
Klip river, South Africa, 393, 397.
Klippfontein, South Africa, 419, 421, 422, 424, 429.
Klipriversberg, South Africa, 395, 397, 398, 451.
— dyke, South Africa, 453.
Knight's gold-mine, South Africa, 418.
Knobydorne, wood, Matabeleland, 30.
KNOWLES, JAMES, JUN., quoted, 254.
KOCH, DR., quoted, 435, 457.
KOEPE, balance-rope system, 74.
Kohlen-carbonite, composition, 167.
Komati, Transvaal, 378.
Kongsberg, Norway, anthracite, 428.
Koonap beds, South Africa, 400.
Koondah hills, India, gold-mines, 346, 349.
Koorumber tribe, India, 354.
KOSSMANN, DR., dust-firing in brown-coal briquette works, 574.
KOTSOVSKY, N., composition of mine-atmospheres in the Donetz coal-field, Russia, 620.
KÖTTGEN, C., electric power-transmission in mines, 599.
Kowie, South Africa, quartzites, 398.
KRENKE, GUSTAV, Donetz coal-field, Russia, 594.
Krondraai, South Africa, 397.
Kronstad, South Africa, coal deposits, 401.
Krugersdorp, South Africa, 382.
Kumaon, gold-dust as money, 346.

La Grange pit, winding-engine, 213.
Labour cost, India, 353.
— —, roasting of ores, 375.
— —, underground haulage, Cannock and Rugeley collieries, 571.
Labourers, Indian gold-mines, 362.
—, Matabeleland, 30.
Ladysmith, South Africa, coal-deposits, 401.
Lake district, Coniston district, 553, 554.
— Superior, copper-bearing conglomerates, 458.
— —, fire at Anaconda mine, 93.
LAMBOTTE, C., gas and petroleum motors, 602.
Lamps, acetylene, 573.
Lanarkshire, coal-output, 258.
—, correlation of coal-seams, 89, 90.
Lancashire, 554, 555.
—, accidents, 136.
— boilers, 324, 325, 326, 328, 329, 332, 333, 334, 335, 338, 499.
— —, Birley collieries, 84.
— —, costs, 199, 200.
— —, Moss Hall collieries, 558.
— —, Nunnery collieries, 80, 81.

Lancashire boilers, Park collieries, 556.
—, coal, analysis, 544.
—, coal-field, 554.
—, coal-measures, 146, 147, 148, 149.
—, comparative mortality of miners, 243, 244.
—, explosions of fire-damp or coal-dust, 528, 651, 652.
—, Giggleswick, 343.
—, keuper formation, 27.
—, south, coal-field, 147.
—, — , permian measures, 27.
—, —, zechstein permian, 26, 562.
— and Warwickshire coal-fields, depth to productive coal-measures between. —Discussion, 21, 561.
Lancashire-Cheshire coal-region, 144.
Lancaster gold-mine, South Africa, 449.
Lang laid wire-ropes or cables, 372.
Langlaagte, South Africa, 412.
— block B gold-mines, South Africa, 449.
— estate, South Africa, 412.
— — gold-mines, South Africa, 449.
— royal gold-mine, South Africa, 449.
— united gold-mines, South Africa, 449.
Lap and lead of winding and other engines, 64.—Discussion, 68, 233.
Lapierre, M., coal in the Transvaal, 597.
Lapparent, Prof. de, quoted, 386.
Lapworth, Prof., quoted, 12.
Laval, steam turbine, 603.
Launay, L. de, geological description of the gold-mines of the Transvaal, Witwatersrand, Heidelberg, and Klerksdorp districts, 378.
Lawn, James Gunsen, election, N.E., 518.
Layland, Ald., mayor of Wigan, 517.
Leach, C. C., *lead and lap of winding and other engines*, 71.
—, *report of the explosives committee*, 178.
Lead and lap of winding and other engines, 64.—Discussion, 68, 233.
Lead-ore, South Africa, 432.
Leasowe, lighthouse, 554.
Leeds, 18, 20, 343.
—, Beeston coal-seam, section, 166.
—, Messrs. Fowler and Co., winding-engines, 207.
—, traction-engines, 284.
Lees and Davies, quoted, 148.
Legislation, influence of mining, 249.
Leicestershire, 11, 17.
—, coal-field, 9, 12, 18, 19, 144.
—, granite quarry company, traction-engines, 286.
Leinster, coal-measures, 152.
Lemuria plateau, 399.
Lenderyou, Percy, 212.
Lens, sinking shafts, by freezing, 297.
Lepidodendron, South Africa, 401.
Leproux, —, combustible gas in a non-fiery mine, 612.
Leven colliery, pumping-engine tests, 100, 101.
Lewes, Prof. Vivian B., mining explosives.—Discussion, 121, 166.
—, quoted, 178.
Lewis, George, *eastern limits of the Midland coal-field*, 18.
—, *fencing-gates for winding-shafts*, 156, 158.
—, *how a mine may be dry but not dusty*, 141.
—, vote of thanks to authorities of Firth college, 75.
—, *Yorkshire and Nottinghamshire coal-field*, 153, 155.
Lewis and Marks, Vereeniging, South Africa, coal-deposits, 401.
Liassic formation, 13, 14, 152.
— —, Yorkshire, 148.
Lickey hills, 16.
Liddell, John, election, N.E., 518.
Lidgett colliery, electric coal-cutting, 501.
Lightley, John, election, N.E., 174.
Lignite, Bohemia, experiments, 326.
Lilleshall colliery, 559.
Limerick, coal-measures, 151.
Limestone, carboniferous, 14.
—, —, Mendip hills, 562.
—, —, North Wales, 553, 554.
—, —, South Africa, 455.
—, deep-water, 150.
—, dolomitic, South Africa, 395, 396, 398, 427, 430.
—, lower, 152.
—, magnesian, 342.
—, mountain, 11, 22.
—, —, North Wales, 554.
—, silurian, 17.
—, South Africa, 385, 397, 432, 453.
—, spirorbis, 22, 24.
Limpopo river, South Africa, 393.
Linby colliery, 154.
Lincoln, 343.
Lincolnshire, eastward extension of the Yorkshire and Nottinghamshire coal-field beneath the permian and secondary strata into, 143.—Discussion, 150.
Lindop, J., quoted 271.
Lingula flags, North Wales, 553.
Liquid ammonia, 298, 300, 301, 302.
Little Ormes head, North Wales, 553,
Liverpool, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, pebble beds, 562.
— and Manchester, permian rocks between, 561.
— to Menai bridge, notes on the features of the coast of North Wales, 552.
Liversedge, Beeston coal-seam, section, 166.
Llanberis slates, North Wales, 552.
Llanbradach colliery, Cardiff, winding-engines, 207.

Llandudno, North Wales, copper ore, 553.
Llanerch colliery, explosion, 512.
Lloyd and Lloyd, electric welding plant, 41, 54.
Lobengula, king of Matabeleland. 29.
Lockett, James, *cut off gear for winding-engines*, 116.
—, *use of petroleum in safety-lamps*, 109.
Locomotive boilers, 332,
— engines, lead and lap, 68.
Locomotives, electric, 479.
—, road, 279.—Discussion, 291.
— with separate steam and exhaust valves, efficiency of, 637.
Loevy, Dr. J., election, N.E., 216.
Loewy, J., gold extraction by potassium cyanide, 623.
Loire river, France, 385.
Lomagunda country, South Africa, 33.
London and North-Western railway, 561.
— — — — —, boring, 14.
— — Paris, Berthon telephone transmitter, 124.
— basin, 14.
— electric supply corporation, Deptford station, 462.
— to Bombay or Calcutta, freights, 260.
Long John reef, Matabeleland, 37.
Longbotham, Jno., *council's annual report*, M., 490.
—, member of council, election, 490.
—, — — —, —, M., 490.
Longden, J. A., vote of thanks to G. A. Mitchell, 75.
Longridge, M., quoted, 330.
Longton, pebble beds, 562.
Longwall-faces, electric coal-cutting, 492. —Discussion, 501.
Longwall mining machine, Mitchell, 180, 183, 199, 205.
Lord Clive, quoted, 346.
Lord Kelvin, quoted, 256.
Lough Neagh beds, Ireland, 153.
Louis, D. A., *coal-washing plant*, 60.
Louis, Prof. H., *coal-cutting by machinery*, 204, 205.
—, *Kent coal-field*, 550.
Lourenço Marquez, Delagoa bay, railway to Pretoria, 401.
Love, John, *Müller smoke and gas-mask*, 248.
Low Moor, black bed coal-seam, 166.
— —, iron, 47, 48, 49.
Lower bunter, 25, 26.
— —, Nottinghamshire, 339, 340, 343.
— — sandstone, 23.
— cambrian, conglomerate, North Wales, 552.
— carboniferous, 9, 11, 13, 17, 21, 23, 342.
— —, South Africa, 398, 399.
— chalk formation, Suffolk, 15.
— devonian, South Africa, 398.
— gondwánas, India, 400.
Lower limestone, 152.
— — shale, 22.
— permian, 21, 26.
— sandstone, 342.
— Silesia, haulage installation at Fuchs colliery, 631.
— silurian, 13, 14.
— —, North Wales, 553.
— —, Suffolk, 15.
Lugar, Ayrshire, coal-seams, 90.
Luipardsvlei, South Africa, 393, 410, 427.
Lydenburg, Transvaal, 378.
— beds, South Africa, 399.
Lyell and Faraday, quoted, 220.
Lymm, 22.

MacArthur-Forest, cyanide process, 263.
McDonnell, —, 482.
McGowan, E. and W. R. Bell, haulage at Wearmouth colliery, 221.
McIlhiney, P. C., gold extraction: Cassell-Hinman bromine process, 622.
McKinnel and Buchanan, engine indicator, 102.
McLaren, John, road locomotives, 279.—Discussion, 291.
McLaren, J. and H., improved wheel, 282.
Machoopie, labourers, Matabeleland, 30.
Mackworth, Herbert, quoted, 251, 253.
Madagascar, 399.
Madeline estate, South Africa, 430.
Madras gold-field, India, 355.
— railway, Bangalore branch, India, 355.
Mafeking, Matabeleland, 30, 460.
Magaliesberg series, South Africa, 393, 394, 395, 398, 399.
Magnesian limestone, 342.
Magnetic survey, Belgium, 343.
Magnetiferous sandstones, South Africa, 384.
Magnetite-grits, South Africa, 383, 384, 394.
Magnetites, India, 351.
—, South Africa, 381, 382, 383, 424.
Mahoba-hoba, wood, Matabeleland, 30.
Mahomed of Ghazni, 345.
Main coal-seam, Leicestershire, 12.
— reef, Transvaal, 384, 412, 413, 419, 421, 422, 434, 438.
— — leader, Transvaal, 384, 387, 394, 413, 414, 415, 416, 417, 420.
— — series, Transvaal, 381, 386, 388, 394, 395, 405, 409, 410, 418, 419, 422, 423, 426, 427, 429, 435, 438.
Main-and-tail rope haulage, Cannock and Rugeley collieries, 564, 565, 566, 567, 568, 570, 571.
Malabar, gold and silver mines, 346.
Malcolm, Jas., *duty of pumping-engines*, 238, 239.
—, *health condition of coal-miners*, 248.
—, *Müller smoke and gas-mask*, 248.
Malldraeth bay, North Wales, 554.

Mallesons lode, Madras, India, 356.
Malmani, South Africa, 397.
— plateau, South Africa, 399.
Malmesbury beds, South Africa, 399.
Manchester, 20.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, electric motor, 498.
—, road locomotives, 283.
—, Sheffield and Lincolnshire railway, 81.
— and Liverpool, permian rocks between, 561.
Manganese, North Wales, 553.
— dioxide, 159.
— —, South Africa, 432.
— ores, roasting, 635.
Manicaland, Africa, gold-bearing rocks, 348.
Manor farm, Halesowen, shafts, 16.
Mansfeld, cupriferous sulphides, 456.
Manufacture of hard coke, recovery of bye-products.—Discussion, 174.
Mapanie, wood, Matabeleland, 30.
Marie-Louise gold-mine, South Africa, 429.
— — estate, South Africa, 422.
Marine boilers, 332.
Market Weighton, Yorkshire, 148.
MARKHAM AND COMPANY, Broad oaks ironworks, 84.
Marl, new red, 13, 21.
MARSAUT, J. B., safety-lamps, 104, 107, 108, 109.
—, — —, Park collieries, 557.
Marsh gas from wells, 268.
MARTEL, E. A., origin of subterranean cavities and their connexion with mineral veins, 621.
MARTIN, DANIEL, election, S., 88.
MARTIN, G. H., election, N.E., 518.
MARTIN, J. S., quoted, 167, 560.
MARTIN, ROBERT, *duty of pumping engines*, 235.
—, member of council, election, S., 88.
—, treatment of timber for use in mines. — Discussion, 90, 231.
Mashonaland, South Africa, 378, 460.
—, — —, magnetite grits, 383.
—, — —, workmen, 30.
Mason college, technical education, 563.
Masons, comparative mortality, 243, 244.
MASSIA, MANUEL SANCHEZ Y., Puertollaño coal-field, Spain, 596.
Matabeleland, South Africa, gold-bearing rocks, 348.
—, — —, gold-fields, 29.—Discussion, 38, 460.
MAULETTE, PETAU DE, Donetz coal-field, Russia, 593.
MAVROGORDATO, A., quoted, 265.
May consolidated gold-mines, South Africa, 449.
Maybach colliery, Germany, laying coal-dust, 134.
Maypole sinking, Moss hall coal company, 557.
Mazoe river, Mashonaland, 460.
MEACHEM, F. G., quoted, 17, 22.
Mechanical roasting of ores, 369.
— stokers, Proctor, 80.
— ventilation, 251.
Mechernich sandstones, Rhenish Prussia, 456.
MEGASTHENES, Greek ambassador in India, 345.
MELLING, —, reversing-gear, 211.
MELLON, HENRY, election, N.E., 173.
MELLORS, J., member of council, election, M., 490.
Menai bridge, notes on the features of the coast of North Wales, 552.
Mendip hills, 144.
— —, carboniferous limestone, 562.
— —, keuper marl, 562.
— —, palæozoic fault, 543.
MENZIES, JOHN, member of council, election, S., 88.
Mercuric oxide, 160.
Mercury, Indian gold-mills, cost, 364.
—, South Africa, 397.
—, Spain, Asturias, 639.
Mersey river, 554.
Mesozoic epoch, 13, 14.
Metallic fumes and dust, interception, of, 619.
Metallurgical department, Sheffield technical school, 78.
Metallurgy, etc., notes of papers on, 573.
Metamorphic rocks, gold-bearing, 347.
Method of firing shots, Roth.—Discussion, 159.
Methods of closing the tops of upcast winding shafts.—Discussion, 122.
— — testing materials, 638.
Metropolitan gold-mine, South Africa, 412, 449.
Meux boring, London, 543.
Meyer and Charlton gold-mine, South Africa, 412, 449.
Mica, South Africa, 380.
Mica-schist, South Africa, 418.
Micaceous quartzite, 12.
— rocks, India, gold-bearing, 347.
— shales, Cape Colony, 383.
— —, South Africa, 399.
MICHEL, LÉON, responsibility for damage caused by industrial establishments in France, 637.
Micklefield colliery, explosion, 502, 503, 508, 509, 511, 526, 527.
Midas gold-mine, South Africa, 430, 455.
Mid-lothian, Burghlee pit, analysis of gas, 272.
— —, — —, experiments with black-damp, 271.
Mid-Sussex, Balcombe, accident from gas in a well, 266, 267.
Middle carboniferous, South Africa, 399.
— chalk, Suffolk, 15.

Middle coal-measures, 13, 22, 23, 25, 26, 27, 28.
— — —, Adderley green, 562.
— — —, Dover boring, 541.
— — —, Flintshire, 553.
— — —, Ireland, 151.
— reef, Transvaal, 394, 420.
Middelburg, South Africa, 403.
—, — —, coal-deposits, 401.
Middelvlei, South Africa, 393, 410, 427.
Middleton main, new hards, 165.
— —, thin coal-seam, 163, 165.
Middlewich, 21.
Midland, coal, analysis, 544.
— coal-field, 144, 146, 147, 148, 149, 153, 154.
— — —, eastern limits, 9.—Discussion, 17.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, explosions of fire-damp or coal-dust, 528, 651. 652.
Miller, George Appleby Bartram, election, N.E., 216.
Milling-costs, India, 353.
— — per ton of ore treated, 364.
Mills, M. H., *Nottinghamshire coal-field*, 342.
Millstone grit, 11, 27.
— —, Flintshire, 553.
— —, North Wales, 554.
Mine owned and worked by miners in France, 636.
Mine-atmospheres in the Donetz coal-field, Russia, composition, 620.
Mine-timber, experiments on, 90.
Mine-tubs, axle-box for, 633.
Mineral veins, origin of subterranean cavities and their connexion with, 621.
Minerals, spectrum analysis, 648.
Miners, asthma, 241, 242.
—, comparative mortality, 244.
—, India, gold-mines, 362.
—, mine owned and worked by, France, 636.
—, phthisis, 245.
Minerva, South Africa, 430.
Mines, electric power transmission, 599, 600, 601.
—, electrical machinery. — Discussion, 125, 228.
—, how a mine may be dry but not dusty, 128.—Discussion, 136.
—, inspectors, influence of, 249, 250.
—, non-fiery, combustible gas, 612.
—, notes of papers on the working of, 573.
—, photometric values of, and notes upon, various illuminants used in mines.—Discussion, 155.
—, plastic clay, inflammable gas, 613, 614.
—, treatment of timber for use in.—Discussion, 90, 231.
Mines, use of steel girders in.—Discussion, 62.
—, ventilation, 250, 251.
Mining, coal, health conditions of, 240.
—, India, costs, 353.
— and geological millennial congress, Buda-Pest, Hungary, 88.
— — milling costs, Mysore and Nundydroog gold-mines, India, 364.
— explosives.—Discussion, 121, 166.
— legislation, influence of, 249.
— picks, India, 346.
— scholarships, technical instruction committee, Staffordshire county council, 170.
— timber, Matabeleland, 30.
Minnikin, John, election, M., 117.
Miocene period, Ireland, 152.
Mirfield, Beeston coal-seam, section, 166.
Mitchell, G. A., *coal washing plant*, 61.
—, *duty of pumping-engines*, 238, 239.
—, *eastern limits of the Midland coal-field*, 21.
—, *electric welding*, 54.
—, *freezing process of shaft sinking*, 304.
—, *gold-fields of Matabeleland*, 39.
—, *health condition of coal-miners*, 248.
—, *lead and lap of winding and other engines*, 75.
—, *Müller smoke and gas-mask*, 248.
—, *Nottinghamshire coal-field*, 343.
—, *photography in the technology of explosives*, 8.
—, *powdered coal for firing steam-boilers*, 336, 338.
—, president, election, S., 88.
—presidential address, 249.—Discussion, 263.
—, *suffocative gas met with in wells, etc.*, 273.
—, vote of thanks to, 75.
—, — — — — the institution of civil engineers, 461.
Mitchell, J. L., longwall mining machine, 180, 183, 199, 205.
Mitchell, T. W. H., *electric welding*, 230.
—, *methods of closing the tops of upcast winding shafts*, 123.
—, secretary and treasurer, election, M., 490.
Modderfontein, South Africa, 381, 389, 390, 391, 392, 393, 400, 417, 418, 419, 420, 421, 422, 423. 424, 428, 429.
—, — —, gold-bearing beds, 402.
— gold-mine, South Africa, 405, 406, 411, 455.
Mode of operating percussion coal-cutters, 190.
Modern coal-tipplers.—Discussion, 171.
Molteno, South Africa, coal deposits, 401.
Molyneux, South Africa, 426.
Monarch reef, South Africa, 384.
Monckton, G. F., election, N.E., 518.
Monmouthshire, comparative mortality of miners, 243, 244, 245.

Montana, U.S.A., Bi-metallic mining company, Phillipsburg, 373.
Monthly output of gold of the Witwatersrand district, present method of declaring, with a suggestion for its alteration, 624.
Mooi valley, South Africa, 397.
Moore, Joseph, hydraulic pump, 236.
Moore, Wilson, quoted, 392, 427.
Moorhole, 81.
Moorshedabad, India, treasure vaults, 346.
Morecambe, Lancashire, 554
Morgan, Dan, election, S.S., 563.
Morley, Beeston coal-seams, section, 166.
Morse, Willard, S., election, N.E., 216.
Mortality, comparative, in different occupations, 244.
Mortier, —, advantages of compressed air, 602.
Moss hall coal company, 557.
Moss-tamping, 4.
Motherwell, plate picking-band, 255.
Motive power, coal-cutting, 180.
Motor-armatures, 312.
Motor-bedplates, 306.
Motor-magnets, 311.
Motors, 310, 312, 313.
—, gas and petroleum, 602.
Mottram, T. H., gold-fields of Matabeleland, 460.
Mount Sorrel, Leicestershire, 13.
Mountain limestone, 11, 22.
— —, North Wales, 554.
Mouse, sensitive to carbon monoxide, 505.
Mud-stones, Matabeleland, 32.
Mueseler, —, safety-lamp, 104, 107, 108.
Muir, —, *duty of pumping-engines*, 239.
Müller, Prof. Max., quoted, 345.
Müller, —, smoke and gas-mask, 248, 483.
Multitubular boilers, 324.
Murchison, Sir Roderick I., quoted, 10, 11, 19, 21, 26.
Murchison range, Transvaal, 378.
Murton coal-washing plant, 60, 80,
Mysore, India, gold-fields, 348, 355.
—, —, — —, statistics, 366, 367.
— gold mines, India, 357, 358, 359.
— — —, —, statistics, 361, 362, 363, 364, 365, 366.
— reefs gold mines, India, statistics, 366, 367.
—, south-east, gold-mines, India, 359.
— west gold-mines, India, 359.
— — — —, —, statistics, 366, 367.
— Wynaad gold-mines, India, 359, 366.
— — — —, —, statistics, 366, 367.

Namaqualand, South Africa, strata, 399.
Napier, Dr., quoted, 345.
Nareae, mines of gold and silver, 346.
Nash, H. B., adjustable piston-rings, 121.
—, *alteration of rules, M.*, 227.
—, *electrical machinery for mines*, 125.
—, member of council, election, M., 490.
—, *mining explosives*, 122.
—, *notes on sinking at Acton hall colliery*, 162.
—, *Roth method of firing shots*, 162.
—, *telephonic communications in coal-mines*, 125.
Nasmyth, Dr., quoted, 245.
Nason, Frank L., auriferous gravels of the upper Columbia river, British Columbia, 626.
Natal, South Africa, coal-deposits, 401.
—, — —, Karoo beds, 401.
Natives employed in Indian gold-mines, 362, 364.
Nature and sources of suffocative gas met with in wells: together with further observations on the black-damp of coal-mines, 265.—Discussion, 273.
Naumann, Alex., combustion of coal in air, 580.
Neal, John, Jun., election, M., 485.
Needle-weirs, 599.
Needlerock hills, India, 349, 350.
Neill, James H., Camp Floyd mining district, Utah, U.S.A., 627.
Neston, Cheshire, coal-washing plant at Wirral colliery, 55.—Discussion, 59.
Netherseal, bore-hole, 18.
— colliery company, borings, 12.
Netherton, crown best iron, 48, 49.
Neumann, Victor V., powdered coal-firing, 576.
Neuropteris rarinervis, 541.
— Scheuchzeri, 541.
Nevin, John, *causes of death in colliery explosions*, 514.
—, *lead and lap of winding and other engines*, 234.
—, member of council, election, 490.
—, *mining explosives*, 121, 122.
—, *notes on sinking at Acton hall colliery*, 164. 233.
—, *Roth method of firing shots*, 162.
—, *telephonic communications in coal-mines*, 124.
New blue sky gold-mine, South Africa, 418.
— chimes gold-mine, South Africa, 391, 419, 449.
— comet gold-mine, South Africa, 418.
— Crœsus gold-mine, South Africa, 435, 438, 449.
— Heriot gold-mine, South Africa, 412, 417, 449.
— Kleinfontein gold-mines, South Africa, 449.
— primrose gold-mines, South Africa, 449.
— red marl, 13, 21.
— — sandstone, 12, 16, 274, 561, 562.

New Rietfontein gold-mines, South Africa, 449.
— Zealand, gold-mining, 263.
Newcastle, coal analysis, 544.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, South Africa, coal-deposits, 401.
Newdigate, —, bore-hole at Bedworth, 19.
Newent, coal-seams, 24.
Newstead colliery, 154.
Newton colliery, 91.
Niddrie collieries, fire, 92.
— —, Moore hydraulic pump, 236, 237.
Nièvre, France, 385.
Nigel, South Africa, 393, 432.
—, — —, gold-bearing beds, 402.
— gold-mine, South Africa, 390, 391, 392, 393, 406, 419, 423, 424, 449, 451, 455.
— reef, South Africa, 422, 423, 424, 425, 426.
Nigel-Heidelberg series, South Africa, 425.
Nilgherry hills, India, 349, 350.
— —, —, gold-mining, 346.
Nine reefs gold-mine, India, 359.
— — — —, —, statistics, 366, 367.
Nitrate of ammonium, 5.
— — barium, 167.
— — potassium, 167.
Nitro-glycerine, 3, 167.
Nitro-starch, 3.
Nitrogen from wells, 265, 267, 268, 275, 276, 278.
Nixon navigation, coal, 323.
Nizam's dominions, gold-mining, 346.
Noeggerathiopsis Hislopi, Feistm., South Africa, 400.
Non-fiery mines, combustible gas, 612.
Nord-Deutscher Lloyd, Bremen, water-tube boiler, 324.
Norfolk, 154.
North, —, quoted, 340.
North British railway, Bo'ness dock, 261.
— Cheshire, zechstein permian, 26, 27.
— reef, South Africa, 384, 394, 421, 424.
— Staffordshire, 342.
— —, black-damp, 271, 272.
— —, coal-field, 9.
— —, coal-measures, 26.
— —, coal-tipplers, 171.
— —, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
— —, explosions of fire-damp or coal-dust, 528, 651, 652.
— —, keuper formation, 27.
— —, permian strata, 562.
— Wales, 11.
— —, Anglesea, coal-field, 144.
— —, notes on the features of the coast from Liverpool to Menai bridge, 552.
— — and West Lancashire, explosions of fire-damp or coal-dust, 528, 651, 652.
North Wilts, coal-trough, 542.
North-east Lancashire, explosions of fire-damp or coal-dust, 528, 651, 652.
Northallerton, blowing wells, 269, 274, 276.
Northamptonshire, borings for water, 13, 14.
Northcott, Cecil E., election, N.E., 216.
Northleigh, Oxford, accident from gas in a well, 267.
—, —, analysis of gas, 268.
Northumberland, comparative mortality of miners, 243, 244.
—, explosions of fire-damp or coal-dust, 528, 651, 652.
Northwich, salt union company's boring, 21.
Norway, Kongsberg, anthracite, 428.
Nostell colliery, electric coal-cutting, 501.
Notes of papers on the working of mines, metallurgy, etc., from the transactions of colonial and foreign societies and colonial and foreign publications, 573.
— on the explosion of coal-dust, 536.—Discussion, 539.
— — — geological features of the coast of North Wales from Liverpool to Menai bridge, 552.
— — — sinking of No. 1 pit, Acton hall colliery, with special reference to the thinning out of the Silkstone and Beeston coal-seams.—Discussion, 162, 233.
— upon various illuminants used in mines.—Discussion, 155.
Nottinghamshire, 18, 19.
—, coal-field, 9, 19, 20.
—, — —, southern limit, 339.—Discussion, 341.
—, coal-measures, 154.
—, comparative mortality of miners, 243, 244.
— and Yorkshire coal-field: geological suggestions relative to its eastward extension beneath the permian and secondary strata into Lincolnshire, 143.—Discussion, 150.
Nundydroog gold-mine, Madras, India, 356, 357, 358, 359.
— — —, —, —, statistics, 361, 362, 363, 364, 366, 367.
Nunnery collieries, Sheffield, 79.
Nystagmus, 241, 242.

O Harra, —, quoted, 369.
O'Shea, L. T., *mining explosives*, 169.
—, *Roth method of firing shots*, 159.
Oak-bark, 107.
Oberegger coal-screen, 644.
Observations on the black-damp of coal-mines, 265.—Discussion, 273.
Occurrence of mercury in the Asturias, Spain, 639.
Oddfellows' society, report, 253.

Officers, election, M., 490.
—, —, S., 88.
—, —, W.A.B., N.E., 516.
—, — by ballot, M., 491.
Ogle, Dr., quoted, 243, 245, 246,
Ohio, coal-cutting by machinery, 180.
Oil and tallow, costs, Indian gold-mines, India, 353, 364.
Oil-engine, rocket.—Discussion, 170.
Oils, safety-lamps, 104.
—, paraffin, 105.
Old red sandstone, 22.
— — —, South Africa, 383, 384.
Oldham, road locomotives, 283.
Olifant river, South Africa, coal-deposits, 400, 401.
Olifantvlei, South Africa, 430.
Oliver, C. J., *coal-washing plant*, 60.
—, *electric welding*, 52.
Oolite, Yorkshire, 148.
Ooregum gold-mine, Madras, India, 356.
— — —, —, —, statistics, 357, 359, 361, 362, 363, 366, 367.
Ophir of Scripture, India, 345.
Ophitic diabase dykes, South Africa, 396, 451.
Oppermann, —, disengagements of inflammable gas from mines of plastic clay, 613.
Ordovician system, 14.
Ore-concentrators, 640, 642.
Ore-deposits of San Luis, Argentine Republic, 649.
Ores, mechanical roasting, 369.
Oriental gold-mines, Mysore, India, statistics, 367.
Origin and mode of formation of the Witwatersrand auriferous deposits, 452.
— of subterranean cavities and their connexion with mineral veins, 621.
Oriol, Roman, gold-mines of the Duerno, Spain, 623.
Orion gold-mine, South Africa, 396, 428, 430, 438, 440, 449, 457.
Ormerod detaching-hook, 123.
Ormes head, North Wales, 553.
Ormskirk, Shallow Clough, 27.
Orsman, W. J., notes on the explosion of coal-dust, 536.—Discussion, 539.
Orton, Northamptonshire, boring, 13, 14, 15.
Ouchterlony, Colonel, quoted, 354.
Ousthorn, South Africa, 382.
Outbursts of carbonic acid gas, 584, 585.
Output of coal in United Kingdom, 1855 and 1894, 240.
Overseal, 12.
Owthorpe, Nottinghamshire, borehole, 339, 340, 341.
Oxford clay, 270.
Oxfordshire, 19.
—, coal-field, 144, 542,
—, new red sandstone. 562.
Oxfordshire, Northleigh, accident from gas in a well, 267.
—, sewage farm, analysis of gas from sub-soil drains, 268, 270.
Oxide of mercury, 161.
Oxygen, 266, 267, 268, 270, 271, 272, 276, 277, 278.

Paarl central gold-mines, South Africa, 449.
Palapye, Matabeleland, 460.
Palæozoic fault, Belgium and France, 543.
— rocks, 11, 12, 13, 343.
— —, South Africa, 398.
— —, Suffolk, 15.
Palmerston estate, India, 351.
Panton, F. S., explosives committee, 217.
—, *lead and lap of winding and other engines*, 71.
Papers, prizes, 1.
Paraffin, 105.
Parallel ore-roasting furnace, dimensions, etc., 377.
Paris, Belleville water-tube boiler, 325.
—, school of mines, 440.
— and London, Berthon telephone transmitter, 124.
Park collieries, 556.
Parsons, Charles A., *electric welding*, 53.
Parys, South Africa, coal-deposits, 401.
Pas-de-Calais, France, coal-field, 540.
— — —, —, sinking shafts by freezing, 297.
Pauling, —, quoted, 33.
Peak district, Derbyshire, traction-engines, 284.
Peake, H. C., member of council, election, 572.
Pearn pump, Moss hall collieries, 557.
Pearson, A., *treatment of timber for use in mines*, 91.
Pearson, J., *coal-washing plant*, 60.
Pebble beds, bunter, 26, 27.
— —, —, Cannock and Huntington sinking pits, 24.
— —, —, Liverpool, etc., 562.
Pebidian, upper beds, North Wales, 552.
Peninsular and Oriental steam navigation company, 260.
Penmaen Rhos, North Wales, 553.
Pennant grit, 559.
Pennine chain, 146, 147, 552, 554.
Pennsylvania, U.S.A., Alleghany mountains, 145.
—, —, coal-cutting by machinery, 180.
—, —, coal-field, 149.
Penrhyn quarries, North Wales, 552.
Percy, C. M., *some aspects of recent colliery explosions*, 534.
Percussion coal-cutting machines, costs, 199, 200.
Percussion-detonators, 609.
Permanganate of potassium, 159, 161.

Permian, 11, 12, 16, 21, 22, 23, 24, 25, 26, 27, 143, 145, 148.
—, between Liverpool and Manchester, 561.
—, Bohemia, Austria, anthracite, 587.
—, Nottinghamshire. 339, 342, 343.
—, South Africa, 379, 398.
—, lower, 26.
—, upper, South Africa, 400.
—, zechstein, 26, 27, 562.
Permo-carboniferous, 21.
Permo-triassic fossils, South Africa, 398.
PERRET, grate, 321.
PERRY, REV. S. J., quoted, 343.
Perseverance gold-mines, India, 349.
Persians and India, 346.
Perthshire, 144.
Persons employed in coal-mining in United Kingdom, 1855 and 1894, 240.
PETIT, —, continuous and automatic apparatus for taking samples of air or gas, 619.
Petroleum, use of, in safety-lamps, 104. —Discussion, 109.
— and asphalte, Crédo deposit, France, 573.
— engines, 293, 602.
— —, Cleveland mines, 274.
Pewsey vale, coal-trough, 542.
Phalen coal-seam, 181.
Phallic worship, India, 36.
Phillipsburg, Montana, U.S.A., bimetallic mining company, 373.
Phitang, bags of gold-dust, 346.
Phœnicians, Matabeleland, 35.
Photography in the technology of explosives, 2.—Discussion, 6.
Photometric values of, and notes upon, various illuminants used in mines.—Discussion, 155.
Phthisis, miners', 245.
Physicians, comparative mortality, 244.
Picking-bands. 255.
Picks, India, 346.
Pilsen, Bohemia, geology of portion of, coal-basin, 590.
Pindan, bags of gold-dust, 346.
Pine-wood fuel, 375.
Pioneer gold-mine, South Africa, 412, 443.
Pipe-clays, Ireland, Cahir, 153.
Pipes, electric-welding, 51.
Piston-rings, adjustable, 118. — Discussion, 120.
PLATT, JAMES, coal-washing plant at the Wirral colliery, Neston, Cheshire, 55. —Discussion, 59.
PLAYFAIR, DR. LYON, quoted, 543.
PLINY, quoted, 346.
Pliocene, 152, 153.
—, Australia, 434
—, France, 385.
—, U.S.A., California, 434.
Plumbers, comparative mortality, 244.
Plumbiferous nodules, Rhenish Prussia, 456.
Plutonic rocks, South Africa, 380.
Pneumatic winding apparatus, 253, 254.
POETSCH, —, method of sinking, 213.
Poisoning by gas, alcohol in reference to, 275.
POLONCEAU, ERNEST, efficiency of a locomotive with separate steam and exhaust valves, 637.
Polyphase-current motors in mines, 125, 230, 329.
Pont-à-Vendin, France, sinking shafts by freezing, 297.
POPPER, JOSEPH, percussion-detonators, 609.
Porges Randfontein gold-mines, South Africa, 449.
Porphyries, South Africa, 385.
Porphyrites, South Africa, 395, 396, 404, 409.
Porphyritic dykes, South Africa, 451.
Porphyroids, Ardennes, 385, 386.
Portuguese in Africa, 35.
— — India, 346.
Posidonia, Suffolk, 15.
Potchefstroom, South Africa, 380, 381, 397, 426.
Potassium cyanide process for the extraction of gold, 623.
Powdered coal-firing, 576.
— coal for firing steam-boilers: Wegener and other systems, 321.—Preliminary, 321.—Former powdered coal experiments, 321. — Combustion and air supply, etc., 322.—Analysis of gases, 322.—Boiler efficiency, gases, transmission of heat, etc., 322.—Boiler efficiency, 323.—Advantages and disadvantages of powdered coal-firing as compared with large coal, 324.—Powdered coal-firing: various systems, 324. — Practical application of the Wegener system to steam-boilers, 324. —Description of Wegener system of using powdered coal, 325.—Wegener system experiments, 326. — Experiments on a Cornish boiler with powdered coal, Wegener system, at Berlin, by the author, 1893, 326.—Schwartzkopff system of powdered coal-firing, 327. — Experiments at Berlin in 1894 on a two-flued boiler with Schwartzkopff powdered coal-firing. 328.—Friedeberg system of powdered coal-firing, 328. — Ruhl system of powdered coal-firing, 329. —De Camp system of powdered coal-firing, 330.—Powdered coal under the microscope, 331.—Loss due to dirty boiler-plates, 331.—Variations of efficiency due to hand-stoking, 332.—Appendix.—Analysis of furnace-gases from various types of steam-boilers using large coal, 332.—Discussion, 332.

Power-transmission in mines, electric, 599, 600, 601.
Powk hill, Walsall, 25.
Pratt, Miles, election, N.E., 518.
Pre-Cambrian rocks, 27.
Precautions necessary in the use of electricity in coal-mines, 306.—Shocks, 306.—Main conductors, 307.—Junction boxes, 309.—Switches, 309.—Motors, 310.—Motor magnets, 311.—Motor armatures, 312.—Enclosed motors, 313.—Testing, 314.—Discussion, 315.
Present method of declaring the monthly output of gold of the Witwatersrand district, with a suggestion for its alteration, 624.
Presentation, Mr. A. C. Kayll, N.E., 217.
President, election, M., 490.
—, —, S., 88.
Presidential address, G. A. Mitchell, 249.—Discussion, 263.
Prest, J. J., *cut-off gear for winding-engines*, 113, 114.
—, modern coal-tipplers.—Discussion, 171.
Prestatyn, North Wales, 553.
Prestwich, Sir Joseph, quoted, 22, 540, 550.
Pretoria, South Africa, 380, 398.
—, — —, coal-deposits, 401.
Primary epoch, 146.
— rocks, 148.
— —, France, 385.
Prince Jota, 345.
Princess estate, South Africa, 410.
— — gold-mines, South Africa, 449.
Printers, comparative mortality, 244.
Prizes for papers, 1.
Process of shaft sinking by freezing, 297.—Discussion, 304.
Progressit, 3, 4, 5.
Prost, Eugène, fusibility and composition of coal-ash, 586.
Proctor, —, mechanical stoker, 80.
Productive coal-measures between the Warwickshire and Lancashire coal-fields, depth to.—Discussion, 21, 561.
Progressive cut-off gear for winding-engines, Woodworth, 111.—Discussion, 112.
Propfe mill for coal-dust fuel, 574.
Protector safety-lamps, 84.
Prussia, Rhenish, Commern and Mechernich sandstone, 456.
—, —, endless-rope haulage, Roland colliery, 633.
Pterygotus, 16.
Puertollaño, Spain, coal-field, 596.
Pumping-engines, Birley collieries, 82.
— —, duty of, 94.—Discussion, 235.
— —, Moss hall collieries, 557.
— —, Nunnery collieries, 80, 81.
Punjaub, India, gold-mining, 346.
Pyrites, arsenical, copper and iron, India, 351, 354, 355.
Pyrites, auriferous, Brazil, 384.
—, iron, South Africa, 380, 383.
—, —, Spain, Huelva, 383.
Pyrites-pebbles, South Africa, 431.
Pyritiferous conglomerates, South Africa, 396.
Pyritous quartz, South Africa, 350.

Quarter colliery explosion, Scotland, 529.
Quarrymen, comparative mortality, 243, 244.
Quartz, India, 350, 351.
—, South Africa, 403, 407, 453, 456.
Quartz-pebbles, Leicestershire, 12.
— —, South Africa, 379, 385, 386, 431, 436, 455.
Quartz-reefs, India, gold-bearing, 347, 351, 352.
— —, South Africa, 379.
Quartz-sands, France, 385.
Quartz-veins, South Africa, 380, 389, 394, 397, 406, 428, 455, 459.
Quartzites, Hartshill, 13.
—, South Africa, 379, 380, 381, 382, 383, 384, 385, 386, 388, 389, 391, 393, 394, 395, 396, 398, 402, 405, 406, 409, 418, 419, 420, 421, 424, 427, 428, 429, 431, 432, 433, 435, 441, 453, 455, 458.
—, micaceous, 12.
Quartzitic conglomerate, South Africa, 452.
— sandstones, South Africa, 426, 452.
Quartzose conglomerates, South Africa, 385.
— sediments, South Africa, 396.
Queensland, gold in granite and gneiss, 349.
—, refractory gold-ores: their sources and treatment, 631.

Radford, —, quoted, 332.
Radstock, coal-trough, 542.
Rails, imported from U.S.A., 260.
Railway geology, 552.
Railway bars, imported from U.S.A., 260.
Railway rates, 261.
Railways, Caledonian, 261.
—, Manchester, Sheffield and Lincolnshire, 81.
—, North British, 261.
—, South-eastern, 475.
—, South Africa, Johannesburg to Cape Town, 401.
—, — —, — — Durban, 401.
—, — —, Springfontein to East London, 401.
—, — —, Pretoria to Lourenço Marquez and Delagoa bay, 401.
—, South-western, 475.
—, state ownership, 261.
—, Waterloo and city, 475,
Rainfall, India, Colar, 1895, 368.
—. —, Wynaad district, 374.
—, South Africa, Matabeleland, 29.

Rajahs, India, tribute on gold, 354.
RÁKÓCZY, S., experiments with fruevanners, 645.
RAKY, —, system of boring, 582.
RAMSAY, SIR A. C., quoted, 16, 148.
RAMSDEN, EPHRAIM, election, M., 227.
RANCE, C. E. DE, *causes of death in colliery explosions*, 559.
—, notes on the geological features of the coast of North Wales from Liverpool to Menai bridge, 552.
—, *Nottinghamshire coal-field*, 342.
Randfontein, South Africa, 381, 410, 427.
— reef, South Africa, 390, 393, 429.
RANSOME AND SIMS, Ipswich, 291.
Rapazos mine, Brazil, auziferous pyrites, 384.
RAVENSHAW, H. W., precautions necessary in the use of electricity in coal-mines, 306.—Discussion, 315.
Recent colliery explosions, some aspects of, 526.—Discussion, 534.
Recovery of bye-products in the manufacture of hard coke.—Discussion, 174.
Red gneiss, India, 350, 352.
— marl, 14, 21.
— measures, Nottinghamshire, 339, 340.
— noses, Cheshire, 554.
— rocks, 23, 147.
— —, Lancashire, 561, 562.
— sandstone, 557.
— —, new, 12, 16, 274.
— —, old, 22.
— —, —, South Africa, 384.
— upper coal-measures, 23, 24, 26.
Redwick, Gloucestershire, accident from gas in a well, 265, 266, 270, 276.
—, —, analysis of gas, 268, 269, 271.
REED, FRANK, election, N.E., 173.
Refractory gold-ores of Queensland : their sources and treatment, 631.
Refrigerating process of shaft sinking, 297.
REID, ALEX., methods of closing the tops of upcast winding shafts.—Discussion, 122.
Report of council, M., 486.
— — —, S.. 85.
— — the proceedings of the explosives committee. — Discussions, 175, 218, 551.
Resistance-frames, 310.
Respirators for exploring in noxious gases, 560.
Responsibility for damage caused by industrial establishments in France, 637.
Return air-currents, Saar coal-field, Germany, 615.
Reversing-gear, Melling, 211.
Rhaetic system, South Africa, 400.
Rhenish Prussia, Commern and Mechernich sandstones, 456.
— —, endless-rope haulage at Roland colliery, 633.
Rhenoster river, South Africa, coal-deposits, 401.
RHODES, C. E., member of council, election, 490.
—, quoted, 319, 320, 508.
Rhyl, North Wales, boring, 554.
RICHARDS, ARTHUR, election, N.E., 216.
Richmond, boring, 543.
Rietfontein, South Africa, 381, 428, 440, 458.
— gold-mine, South Africa, 409, 451.
— reef, South Africa, 384, 394, 406, 408, 409, 410, 419.
Rietvlei farm, South Africa, 429, 430.
Rig-veda, gold-dust, 346.
Rip, South Africa, 422.
— gold-mine, South Africa, 429.
Road-locomotives, 279.—Discussion, 291.
Roasting hearths, dimensions, 377.
— iron and manganese ores, 635.
— ores, mechanical, 369.
ROBESON, ANTHONY MAURICE, election, N.E. 216.
ROBINSON, GEORGE C., election, S.S, 563.
ROBINSON, R., coal-washing machine, 81.
ROBINSON, WILLIAM, election, M., 227.
Robinson gold-mine, South Africa, 391, 394, 412, 413, 414, 440, 443, 448, 449, 451.
Roburit, 3, 4, 5.
Roburite explosive company, 162, 176.
Rock-drills, Indian gold-mines, 362.
Rocket oil-engine.—Discussion, 170.
RODGERS AND SONS, Sheffield, 76.
ROEBUCK, WALTER, election, N.S., 103.
ROGERS, JOHN M., election, N.E., 216.
Roland colliery, Rhenish Prussia, endless-rope haulage, 633.
Romans in India, 346.
RONALDSON, J. M., AND C. J. GUTHRIE, 529.
Röntgen or X rays, 256.
Roodekop farm, South Africa, 430.
Roodepoort, South Africa, 422.
Ropes, iron-wire, 255.
Roscrea, pipe-clays, 153.
Rosettenstein ridge, South Africa, 429.
Rosettenville, South Africa, 400.
ROSS, J. A. G., *compound winding-engine*, 212.
ROSS, MICHAEL, member of council, election, S., 88.
ROTH, DR., quoted, 160, 161.
—, method of firing shots.—Discussion, 159.
Rothe-todte-liegende series, 21, 26, 27.
ROUTLEDGE, R., *adjustable piston-rings*, 121.
—, *methods of closing the tops of upcast winding shafts*, 123, 124.
ROUTLEDGE, ROBERT, JUN., election, M., 159.
ROWAN, FRED. J., vice-president, election, S., 88.

Rowe, William Henry, election, N.E., 216.
Rowell, William, 482.
Royal navy, analysis of coals suited for, 544.
Ruby property, South Africa. 417.
Rücker, Prof. A. W., prize for paper, 1.
Rücker, Prof. A. W., and T. E. Thorpe, quoted, 343.
Rückgaber, M., detonators for explosives, 607.
Ruddington, Nottinghamshire, bore-hole, 154, 339, 340.
Rugeley and Cannock collieries, underground haulage, 564.
Ruhl system of powdered coal-firing, 324, 329.
Rules, alteration, C., 127.
—, —, M., 227, 491.
Russell, David, election, M., 227.
Russell, James, election, S., 88.
Russia, Donetz coal-field. 593, 594.
—, — — —, composition of mine-atmospheres, 620.
—, petroleum, 104, 108.
—, Urals, Berezovsk, berezite, 380.
—, zechstein fossils, 562.
Rye-meal, 167.

Saar, Germany, testing return air-currents, 615.
Saccharoidal quartz, South Africa, 382.
Safety-hooks, 122, 123, 124.
Safety-lamps, Ashworth-Mueseler, 108.
— —, Birley collieries, 84.
— —, improvements, 252.
— —, Marsaut, 104, 107, 108, 109.
— —, —, Park collieries, 557.
— —, Mueseler, 104, 107, 108.
— —, nystagmus, 242.
— —, oil-burners, 105, 106, 107, 108, 109.
— — oils, 104.
— —, Thorneburry, 109.
— —, use of petroleum in, 104.—Discussion, 109.
St. John gold-mine, South Africa, 422.
— John's collieries, electrical machinery, 229.
— Lawrence river, 198.
— Margaret's bay, channel, 540.
San Luis, Argentine Republic, ore-deposits, 649.
Salisbury, Mashonaland, 460.
— gold-mine, South Africa, 394, 412, 415, 416, 417, 449.
Salop, 17.
—, coal-field, 11.
Salt borings, South Durham, hydrogen, 274.
Salt Union Company, Northwich, boring, 21.
Sandracothus, emperor of India, 345.
Sands, Bourbonnais, France, 385.
Sandstone, calciferous, Scotland, 89.
—, ferruginous, South Africa, 379, 381.
Sandstone, magnetiferous, South Africa, 384.
—, magnetite-bearing, South Africa, 382.
—, new red, 12, 16, 274.
—, — —, Lancashire, 561, 562.
—, old red, 22.
—, — —, South Africa, 384.
—, quartzitic, South Africa, 406, 426, 452.
—, Rhenish Prussia, 456.
—, silurian, North Wales, 554.
—, South Africa, 394, 399, 413, 453.
—, Table mountain, 399.
—, yellow calcareous, 342.
Sandwell park colliery, 16, 17.
Sapcote, Leicestershire, 13.
Sarrau, —, delayed ignition of grisounite cartridges, 610.
Satapatha Brathmana, 346.
Sawyer, A. R., quoted, 382, 383, 397.
Scandrett, Archibald Balfour, election, N.E., 2 6.
Schenk, Prof., quoted, 399.
Schistose beds, South Africa, 420.
— —, India, gold-bearing, 347.
— —, Matabeleland, 32.
Schists, India, gold-bearing, 347.
—, Madras, 355.
Schizoneura, South Africa, 400.
Schloesing, M., Jun., composition of fire-damp, 611.
Schmeisser, Dr. C., gold-mining in Western Australia, 628.
—, quoted, 400, 435, 440, 455, 457.
Schmitz, Rev. G., transport theory of coal formation, 535.
Schneider, C., quoted, 326, 328, 329.
Scholarship examination, North and South Staffordshire, examiners, 572.
Schröder, Von, and W. Smitz-Dumont, smoke question, 580.
Schwartz, Julius, ore-concentrators, 642.
Schwartzkopff, —, system of powdered coal-firing, 324, 327, 328, 328, 329, 330.
Scotland, comparative mortality, 245.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, east, bearer system, 253.
—, explosions of fire-damp or coal-dust, 528, 529, 651, 652.
—, Lanarkshire, coal-output, 258.
—, prices of coal, 259.
—, Quarter colliery explosion, 529.
Scott, W. Beattie, examiner in technical education, Staffordshire county council, 572.
Scott-Anderson, T., electric welding, 40.—Discussion, 52, 230.
Scrutineers, M., 485.
Screening and cleaning of coal, 255.
— plant, Birley collieries, 82, 83.
— —, Nunnery collieries, 80.

Screens, Oberegger, 644.
—, vibromotor, 58, 60, 61.
Seaham colliery, explosion, 580.
Secondary rocks, 9, 143, 148, 159.
Secretary, election, M., 490.
Sedgeley, Dudley, 17.
Self-acting inclines, brake and pulley, 634.
— — waggon-tippler, 649.
Seghill colliery, fan-engine, 71, 74.
SELBY, JOHN BASHLEY, election, M.E., 173,
SEMCOMBE, —, brick-kilns, 81.
Serpentine injector, 288.
SETTLE, JOEL, water-cartridge, 166.
Severn river, 22.
— tunnel, 559.
Sewage farm, Oxford, analysis of gas from sub-soil drains, 268, 270.
Shaft guides, 254.
— —, Nunnery collieries, 79.
Shaft-sinking, Gobert freezing system, 297.—Discussion, 304.
— —, India, costs, 362.
Shakespear cliff, Kent, boring on the Great fall, 540, 544.
— tunnel, Dover, 541.
Shales, South Africa, 379.
—, micaceous, Cape Colony, 382.
Shallow Clough, Ormskirk, 27.
Shangan labourers, Matabeleland, 30.
SHARP, SAMUEL, 13.
Shatterford pit, 24.
SHAW, F. G., gold-fields of Matabeleland, 29.—Discussion, 38, 460.
SHEARD, R., election, M., 117.
—, *electric welding*, 52.
Sheba, Matabeleland, 34.
Sheerness, boring, 542.
Sheffield, electric welding plants, 41.
—, Firth college, 77.
—, German competition, 260.
—, Hutton and Sons, 77.
—, Jessop and Sons, 76.
—, Nunnery collieries, 79.
—, Rodgers and Sons, 76.
—, technical school, 78.
—, Walker and Hall, 76.
SHIPMAN, —, quoted, 340.
Shireoaks colliery, permian rocks, 343.
Shoemakers, comparative mortality, 244.
Shoes and dies, costs, Indian gold-mills, 364.
Shot-firing and coal-dust, 137.
— —, Roth method.—Discussion, 159.
Shropshire, 11, 17, 21, 22, 24.
—, black-damp, 271.
—, coal-field, 11, 19, 26.
SIDGREAVES, REV. W., quoted, 343.
SIEMENS, ALEXANDER, prize for paper, 1.
SIEMENS, dynamos, Deptford station, 465.
SIEMENS BROTHERS AND Co., electric locomotives, 479.
SIEMENS-MARTIN, forged steel crank-shafts, 469.
SIMMONS, ALFRED, photography in the technology of explosives, 2.—Discussion, 6.
Signalling, Cannock and Rugeley collieries, 571.
—, electric, India, Nundydroog gold-mine, 359.
Silesia, lower, haulage installation at Fuchs colliery, 631.
—, powdered coal, firing, 326, 328.
—, upper, fire at Kleophas colliery, 618.
Silica, South Africa, 435, 436, 439.
Silkstone coal-seam, temperature, 231.
Silkstone and Beeston coal-seams, thinning out at Acton hall colliery, 162, 223.
Silkworth colliery, winding-engine, 72.
Silurian, 11, 13, 14, 16, 17, 19, 20, 22.
—, Denbighshire grits, 553.
—, North Wales, 553.
—, South Africa, 379.
—, Suffolk, 15.
— limestone, 17.
— quartzite, 16.
— sandstone, North Wales, 554
Silver-mines, India, 346.
SILVESTER coal-tippler, 171.
Simmer gold-mine, South Africa, 418.
Simmer and Jack gold-mine, South Africa, 388, 391, 403, 412, 417, 449, 451.
SIMON, DR., quoted, 400.
SIMPSON, G. P., BRADY, F., AND NATH. R. GRIFFITH, Kent coal-field, 540.—Discussion, 550.
SIMPSON, J. B., *suffocative gas met with in wells*, 274.
SIMPSON, R. R., *haulage at Wearmouth colliery*, 226.
SIMPSON, T., *haulage at Wearmouth colliery*, 226.
Sinai, ancient copper-mines, 598.
Sinking, Anzin collieries, Vicq pits, 213.
—, Gobert freezing process, 297.—Discussion, 304.
—, Poetsch method, 213.
—, Wearmouth colliery, 221.
Sinking-pumps, Moss hall coal company, 557.
Sinombi district, Matabeleland, 37, 460.
SJÖGREN, PROF. Hj., election, N.E., 174.
Skiddaw slates, North Wales, 553.
Slaughter house hill, South Africa, 394.
SMITH, DR. ANGUS, quoted, 277.
SMITH, C. SEBASTIAN, *fencing-gates for winding-shafts*, 157.
SMITH, HOLROYD, *road locomotives*, 293.
SMITH, J. BAGNOLD, *Nottinghamshire coal-field*, 343.
SMITH, MERVYN, quoted, 345, 347, 357.
SMITZ-DUMONT, W., AND VON SCHRÖDER, smoke question. 580.
Smoke, powdered coal for firing steam-boilers, 327, 328, 329.
— and gas-mask, Müller, 248, 483.
— question, 580.

SNELL, DR. SIMEON, quoted, 241, 242.
SNOW, CHARLES, *electricity in coal-mines*, 315.
Snowdon, North Wales, 552, 553.
Sneyd colliery, Woodworth automatic cut-off gear, 70, 112.
SOAR, EDWARD, election, M., 159.
Société anonyme des houilléres de Saint-Étienne, Treuil collieries, 213.
Some aspects of recent colliery explosions, 526.—Discussion, 534.
Somersetshire, Bristol coal-field, 144.
—. Camerton colliery explosion, 526.
—, coal-field, 11, 149, 543.
—, Mendip hills, 144.
—, Timsbury colliery, analysis of gas, 272.
Somnath, temple of, 345.
SOPWITH, A., vote of thanks to the authorities of Firth college, 75.
Sources and nature of suffocative gas met with in wells; together with further observations on the black-damp of coal-mines, 265.—Discussion, 273.
South Africa, fire at De Beers mine, 93.
— —, geological description of the gold-mines of the Transvaal, 378.
— —, geology, 379.
— —, gold-fields of Matabeleland, 29.—Discussion, 38.
— —, gold metallurgy on the Witwatersrand, 525.
— —, gold-mining, 263.
— —, present method of declaring the monthly output of gold of the Witwatersrand, etc., 625.
— Dakota, U.S.A., golden reward mining company, Deadwood, 374.
— Durham, hydrogen from salt borings, 274.
— eastern railway, 475.
— — — and Channel tunnel company, 540.
— Essex, coal-trough, 542.
— Lancashire, coal-field, 147, 148.
— —, permian measures, 27.
— —, zechstein permian, 26.
— reef, South Africa, 384, 394, 412, 415, 419, 420, 435.
— Staffordshire, 22, 23, 24.
— —, coal-field, 9, 11, 15, 16, 17, 19, 20, 22, 144, 154.
— —, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
— —, explosions of fire damp or coal-dust, 528, 651, 652.
— Wales, coal-field, 11, 543.
— —, coal-seams, 149.
— —, coal-tubs, 131, 138.
— —, comparative mortality, 243, 244.
— —, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
— —, explosions of fire-damp or coal-dust, 528, 529, 651, 652.
— —, mine-atmosphere, 139, 140.
South Wales, Tylorstown colliery, analysis of gas, 272.
— Warwickshire, absence of bunter, 562.
— western district, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
— — —, explosions of fire-damp or coal-dust, 528, 651, 652.
— — railway, 475.
— Yorkshire, coal-field, 19, 143.
— —, coal-seams, 162, 163.
SOUTHALL, ALFRED BRADLEY, election, M., 117.
SOUTHERN, T. A, *how a mine may be dry but not dusty*, 139.
Southern Ayrshire coal-fields. — Discussion, 89.
— limit of the Nottinghamshire coal-field, 339.—Discussion, 341.
— portion of the Valenciennes coal-field, France, 589.
SOWERBY, CHARLES, election, M., 227.
Spain, Asturias, occurrence of mercury, 639.
—, Duerno, gold-mines, 623.
—, Huelva, iron pyrites, 383.
—, iron and copper pyrites, 451.
—, Puertollaño, coal-field, 596.
—, Villanueva, coal-field, 596.
Specific gravity of choke-damp, 266.
Spectrum analysis of minerals, 648.
Spes bona gold-mine, South Africa, 412.
Spirifer antarcticus, South Africa, 383.
Spirorbis limestone, 22, 24.
Spray system of laying coal-dust, 134, 135, 136.
SPRENGEL explosives, 538.
Springfontein, South Africa, railway to East London, 401.
Springs, South Africa, 381.
Stable reef, South Africa, 394.
Staffordshire, Cannock and Huntington, sinking, 303, 305.
—, coal-fields, 19, 20, 149.
—, coal-tipplers, 171.
—, comparative mortality of miners, 243, 244.
— county council, technical education, 563, 572.
— — —, technical instruction committee, 170.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, explosions of fire-damp or coal-dust, 528, 651, 652.
—, north, 342.
—, —, black-damp, 271, 272.
—, —, coal-field, 9, 26.
—, —, keuper formation, 27.
—, —, permian, 562.
—, south, 22, 23, 24.
—, —, coal-field, 9, 11, 15, 16, 17, 19, 20, 22, 144, 154.
STAGG, —, quoted, 331.
Stamps, Colargold-field, India, Mysore, 366.

Standard horse-shoe calcining furnace, dimensions, etc., 377.
Stanhope gold-mines, South Africa, 449.
Stanley heading machine, 181.
Stanniferous veins, South Africa, 380.
Stanton colliery, electric coal-cutting, 501.
— gate, Nottinghamshire, trial shaft, 339.
State ownership of railways, 261.
Statham, —, quoted, 271.
Statistics, Johannesburg Chamber of Mines, South Africa, 449.
Stead, —, carbon-ball transmitter, 124.
Steam boilers: powdered coal for firing, Wegener and other systems, 321.—Discussion, 332.
— jet, ventilation, 251.
— plough, 279, 291.
— turbine, Laval, 603.
Steamer geology, 552.
Steavenson, A. L., *compound winding-engine*, 212.
—, *freezing process of shaft-sinking*, 304.
—, presentation to A. C. Kayll, 217.
—, *powdered coal for firing steam boilers*, 332.
—, *road locomotives*, 293.
—, *suffocative gas met with in wells, etc.*, 274.
Steel, cost, India, 353.
—, electric welding, 473.
— barrels, electric welding, 51.
— girders, use of, in mines.—Discussion, 62.
— pipes, electric welding, 51.
— wire-ropes, 255.
Steele, Wm. Robley, election, M., 159.
Stemming, length of, 219, 220.
Stephenson, George, quoted, 279.
Stephenson, Shadrack, election, M., 117.
Stephenson and Co., Newcastle-upon-Tyne, steam plough, 291.
Stevenson, Dr., quoted, 267.
Stévart, A., Laval steam turbine, 603.
Steyn estate, South Africa, 430.
Stockingford shales, 13.
Stockport, permian rocks, 562.
Stokes, A. H., *eastern limit of the Midland coal-field*, 18, 20.
—, *electricity in coal-mines*, 315.
—, *fencing gates for winding-shafts*, 156, 157.
—, *gold-fields of Matabeleland*, 38.
—, *how a mine may be dry but not dusty*, 137.
—, *photography in the technology of explosives*, 6.
—, photometric values of, and notes upon, various illuminants used in mines.—Discussion, 155.
—, quoted, 242.
—, *report of the explosives committee*, N.E., 175.
Stolz, Fr., haulage installation at the Fuchs colliery, Lower Silesia, 631.
Stone, Arthur, election, N.E., 216.
Stone-breakers, Blake-Marsden, Ooregum gold-mines, India, 359.
Stone-lined shafts, Matabeleland, 39.
Stony Stanton, Leicestershire, 13.
Storey, T. E., *causes of death in colliery explosions*, 561.
Stormberg beds, South Africa, 400, 401.
Strength of electric welded, bars, 48.
Strick, Colonel, rocket oil-engine, 171.
Striped pebbles reef, South Africa, 386.
Struvé, —, fan, 252.
Students' meeting, 221.
Stutton, Suffolk, boring, 15, 18, 20.
Subterranean cavities and their connexion with mineral veins, 621.
Suess, Prof., quoted, 399.
Suffocative gas met with in wells; nature and sources of, together with further observations on the black-damp of coal-mines, 265.—Discussion, 273.
Suffolk, 154.
—, borings, 15.
Sullivan Machinery Company, 183.
Sulphate of magnesium, 167.
Sulphide of mercury, 161.
Sulphur, 160.
— springs, Chillington, near Codsall wood, 25.
Sussex, Balcombe, accident from gas in a well, 266, 267.
Sutcliffe, R., *notes on sinking at Acton hall colliery*, 162.
Sutton, W., scrutineer, M., 485.
Sutton colliery, electric coal-cutting, 501.
Swallow, R. T., explosives committee, 217.
Swazi beds, South Africa, 399.
Swaziland, South Africa, coal-deposits, 401.
—, — —, gold-bearing districts, 399.
Swindon, boring, 25.
Switches, electric, 309.
Syenite, India, Madras, 355.
—, Leicestershire, 13.
Symon fault, 25.
System of working coal-cutting machinery, 197.

Table mountain, Cape Town, 398, 399.
— —, — —, fossils, 397.
— —, — —, granites, etc., 383.
Tailings, costs of amalgamation, Indian gold-mills, 365.
Tailors, comparative mortality, 244.
Talcose rocks, India, gold-bearing, 347.
— schists, India, Madras, 355.
— —, South Africa, 399.
Talk-o'-the-hill colliery, analysis of gas, 272.
Tallow, cost, India, 353, 364.
Tank block gold-mine, Mysore, India, statistics, 366.

Tamarac, Lake Superior, copper-bearing conglomerates, 458.
Tartars in India, 346.
Taylor, John, and Sons, quoted, 360.
Teall, J. J. H., *Nottinghamshire coal-field*, 341.
Technical education, Staffordshire county council, 563, 572.
— instruction committee, Staffordshire county council, 170.
— school, Sheffield, 78.
Technology of explosives, photography in, 2.—Discussion, 6.
Telephonic communications in coal-mines.—Discussion, 124.
Tensile strengths, electric-welded bars, 48.
— —, hand-welded bars, 49.
Terebratulæ, South Africa, 397.
Tertiary epoch, 405.
— lakes, France, 391.
— rocks, 152.
— —, India, 348.
— —, Suffolk, 15.
Testing materials, methods of, 638.
— return air-currents in the Saar coal-field, Germany, 615.
Thermometer, etc., readings, 1895, 651.
Theta reef, Matabeleland, 37.
Thinning out of the Silkstone and Beeston coal-seams at Acton hall colliery, 162.
Thirkell, E. W., *alteration of rules*, M., 491.
—, *council's annual report*, M., 490.
—, *electric coal-cutting on longwall faces*, 501.
—, *Roth method of firing shots*, 161.
—, *treatment of timber for use in mines*, 232.
—, vice-president, election, M., 490.
Thomas, Reginald, election, S.S., 563.
Thomson, Dr. Tatham, quoted, 242.
Thomson, —, system of electric welding, 40, 52, 53, 472, 473.
Thompson, E., use of steel girders in mines.—Discussion, 62.
Thomlinson, William, election, N.E., 173.
Thorneburry, oil-burner, 105, 106, 107, 109, 110.
—, safety-lamp, 109.
Thornewill and Warham, automatic cut-off, 79.
Thorneycroft, Wallace, vice-president, election, S., 88.
Thornhill, Yorkshire, 165.
— collieries, Yorkshire, coke, 61.
Thornley, —, quoted, 65.
Thornley-Walters, expansion gear, 68, 69, 70, 71, 72, 74.
Thorpe, T. E., and Rücker, A. W., quoted, 343.
Thrybergh hall colliery, 122.
Thurston, Prof., quoted, 335.
Timber, India, cost, 353, 364.
Timber, Matabeleland, 29, 30.
— for use in mines, treatment of.—Discussion, 90, 231.
Times, Henry, election, N.E., 174.
Timsbury colliery, analysis of gas, 272.
— — explosion, 271.
Tipperary, coal-field, 152.
—, pipe-clays, 153.
Tipplers, self-acting, 640.
Titanite, South Africa, 382.
Titterstone clee hills, 24.
Tourmaline, South Africa, 430.
Traction-engines, 279.—Discussion, 291.
Transmission of power in mines, electric, 599, 600, 601.
Transport theory of coal-formation, 585.
Transvaal, South Africa, 36.
—, — —, coal, 597.
—, — —, coal-deposits, 401.
—, — —, copper workings, 36.
—, — —, geological description of the gold-mines, etc., 378.
—, — —, Karoo beds, 401.
Trasenster, Paul, Donetz coal-field, Russia, 593.
Treasurer, election, M., 490.
Treasury gold-mine, South Africa, 412.
Treatment of timber for use in mines.—Discussion, 90, 231.
Tremolite, South Africa, 397.
Trent river, 9.
— valley, 342.
Trentham, boring, 562.
Treuil collieries, 213.
Triassic formation, 9, 11, 12, 13, 14, 23, 25, 26, 148, 152.
— —, Cheshire, 562.
— —, Lancashire, 554.
— —, Nottinghamshire, 339, 342, 343.
— fossils, South Africa, 398, 400 401.
Trimpley, 23.
Tubs, axle-box for, 633.
—, form of, 131, 135, 137, 138.
—, Wearmouth colliery, 222.
Tunbridge Wells sand, 270.
Turbine, Laval, 603.
Turnford, boring, 543.
Tyldesley colliery, electric coal-cutting, 501.
Tylorstown colliery, South Wales, analysis of gas, 272.
— —, — —, colliery explosion, 502, 503, 508, 509, 527.
Tyrone, coal-field, 151.
—, Lough Neagh beds, 153.

Ulster, Tyrone, coal-field, 151.
Undercutting by machinery, 191.
Underground haulage at Cannock and Rugeley collieries, 564 —Cannock Wood mine, 564.—Wimblebury mine, 566.—Valley mine, 567.—Remarks, 568.
United main reef gold mines, South Africa, 412, 449.
— mines, Cornwall, ventilation, 251.

United States, coal-cutting by machinery, 180, 258.
— —, Illinois, coal cut by machinery, 258.
— —, —, Collinsville, zinc works, 375.
— —, Kansas, Argentine, consolidated Kansas city smelting company, 376.
— —, Montana, Phillipsburg, bi-metallic mining company, 373.
— —, South Dakota, Deadwood, golden reward mining company, 374.
— —, Utah, Camp Floyd mining district, 627.
Unwashed coal, analyses of coke, 61.
Upcast winding shafts, methods of closing the tops.—Discussion, 122.
Upper cambrian, 13.
— carboniferous, 14, 554.
— —, South Africa, 379, 398.
— chalk, Suffolk, 15.
— coal-measures, 17, 22, 23, 24, 26, 27.
— — —, Ireland, 151.
— — —, Lancashire, 561, 562.
— Columbia river, British Columbia, auriferous gravels, 626.
— devonian, South Africa, 384.
— —, — —, fossils, 383, 399.
— pebidian beds, North Wales, 552.
— permian, South Africa, 400.
— Silesia, fire at Kleophas colliery, 618.
— —, powdered coal, experiments with, 326.
— silurian, 14, 16.
— trias, South Africa, 400.
Urals, Russia, Berezovsk, berezite, 380.
Use of expansion-gear, 64, 71.
— — petroleum in safety-lamps, 104.—Discussion, 109.
— — steel girders in mines.—Discussion, 62.
Utah, U.S.A., Camp Floyd mining district, 627.

Vaal river, South Africa, 381, 393, 396, 397, 401.
Vale of Clywd, North Wales, 553, 554.
— — Conway, North Wales, 553.
— — Pewsey, coal-trough, 542.
Valenciennes, France, southern coal-field, 589.
VALENTIN, DR. J., ore-deposits of San Luis, Argentine Republic, 649.
Valves, Cornish, 64, 65, 72, 73, 79.
Van Ryn gold-mine, South Africa, 389, 391, 418, 419, 420, 424, 449, 455.
VANHASSEL, PROSPER, brake and pulley for self-acting inclines, 634.
VAUTIN, CLAUDE, election, N.E., 518.
Vellery Mulla hills, India, 349.
— — —, —, gold-mining, 346.
Velocity-diagrams, pumping-engines, 101.
Venterskroom, South Africa, 382.
Ventilation, Birley collieries, 83, 84.
—, Nunnery collieries, 80, 81.
—, Park collieries, 556.
Ventilation, Wearmouth colliery, 226.
— of mines, improvements, 250, 251.
— recorder, Park collieries, 556.
Ventilators, Waddle, 67.
Vereeniging, South Africa, 393, 396, 401.
—, — —, carboniferous fossils, 397, 398.
—, — —, coal-deposits, 401.
VERRIER, U. LE, interception of dust and metallic fumes, 619.
Vertebraria indica, Royle, South Africa, 400.
Vesta gold-mining company, South Africa, 397.
Vibromotor, screen, Wirral colliery, 58, 60, 61.
Vice-chairmen, election, W.A.B., N.E., 516.
Vice-presidents, election, M., 490.
— —, —, S., 88.
Vicq pits, Anzin collieries, sinking, 213.
Victoria falls, Matabeleland, 29.
Village main reef, South Africa, 394, 406.
— — — gold-mine, South Africa, 412, 417.
Villanueva, Spain, coal-field, 596.
VILLOT, —, mine owned and worked by miners in France, 636.
Violet estate, South Africa, 429.
Vitreous quartz, South Africa, 385.
VIVIAN, JOHN, *eastern limits of the midland coal-field*, 18.
VIVIAN DIAMOND BORING COMPANY, 340.
Vredefort, South Africa, 382.
Vogelstruis, South Africa, 429.
Vogelstruisfontein gold-mines, South Africa, 449.

WADDLE, JOHN R., fan, 67, 83, 84.
Waggon-tippler, self-acting, 640.
Waggons, form of, 131, 135, 137, 138.
WAIN, E. B., *causes of death in colliery explosions*, 559.
—, *cut-off gear for winding-engines*, 112, 114, 115.
—, *modern coal-tipplers*, 171, 172.
—, *powdered coal for firing steam-boilers*, 335.
—, *rocket oil-engine*, 170.
—, technical instruction committee, Staffordshire county council, 170.
—, use of petroleum in safety-lamps, 104.—Discussion, 109.
WALCKENAER, C., expansion-dampers for the furnaces of boilers with small water-tubes, 581.
WALCOTT, R. HENRY, election, N.E., 216.
WALES, —, 482.
Wales, explosions of fire-damp or coal-dust, 528, 651, 652.
—, traction-engines, 284.
—, North, 11.
—, —, notes on the features of the coast from Liverpool to Menai bridge, 552.
—, South, coal-field, 11, 543.
—, —, comparative mortality of miners, 243, 244, 245.

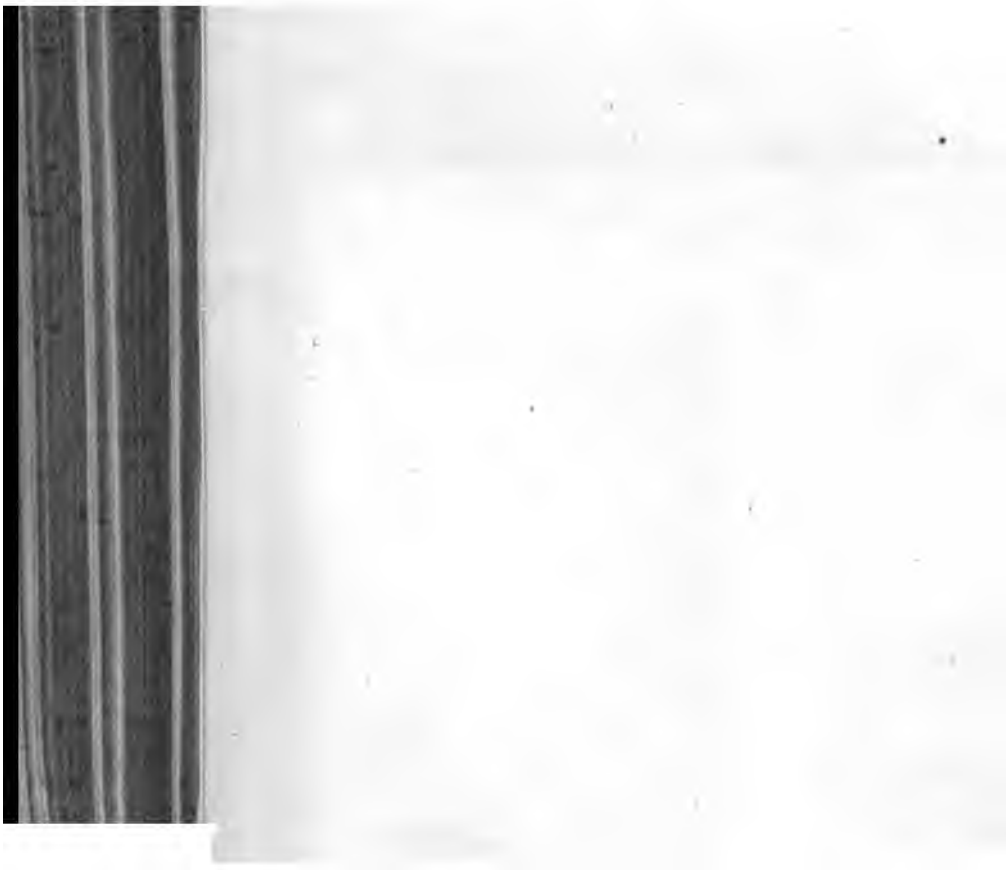
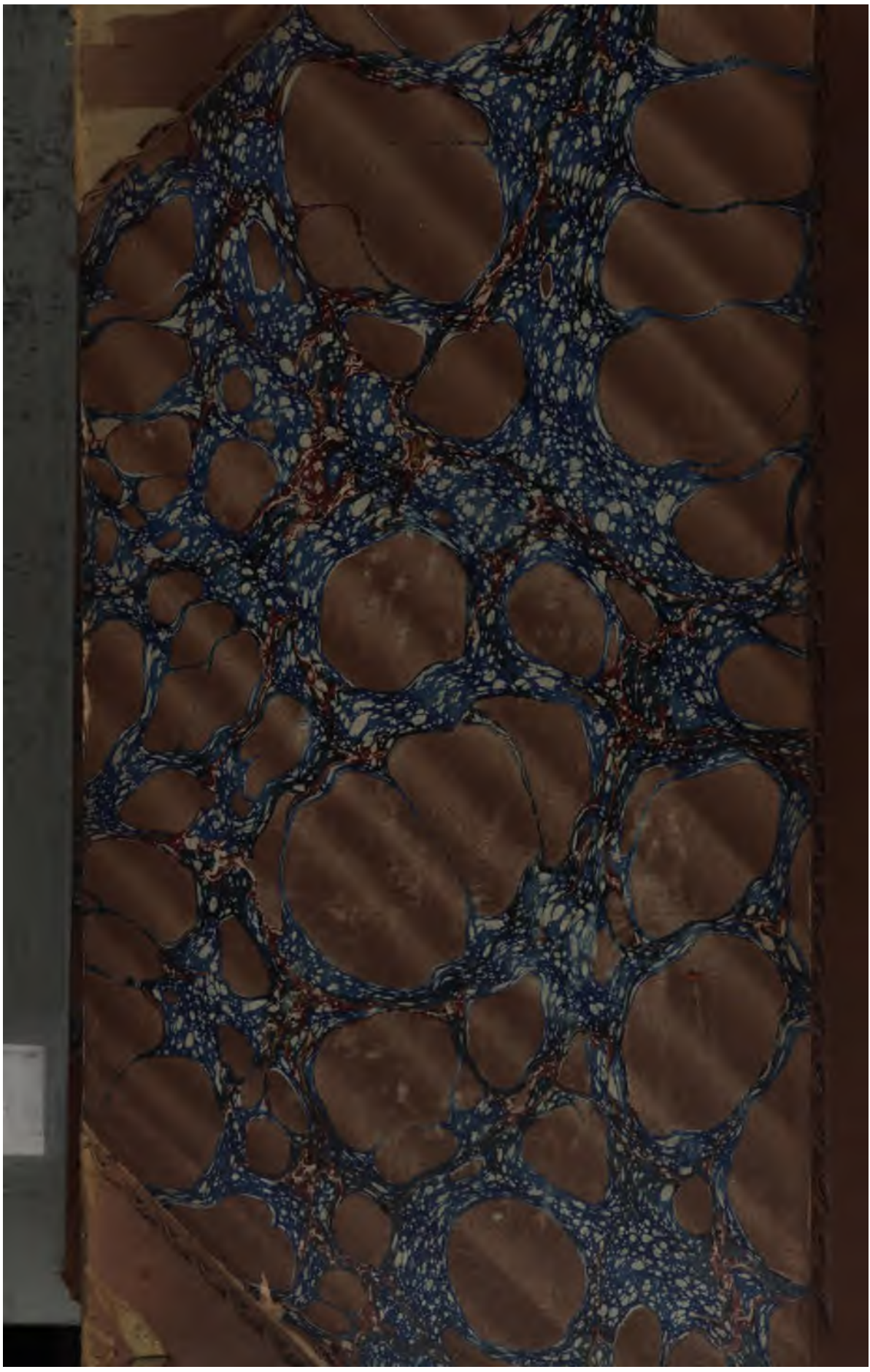
Wales, South, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, —, Tylorstown colliery, analysis of gas, 272.
Walker, George Blake, member of council, election, 490.
—, *mining explosives*, 168.
—, president, election, M., 940.
—, Roth method of firing shots.—Discussion, 159.
Walker and Hall, 76.
Walker fan, 80, 84.
— —, Park collieries, 556.
Wallis-Jones, —, electric-welding, 472.
Walsall, Powk hill, 25.
Walters, Hargrave, lead and lap of winding and other engines, 64.—Discussion, 68, 233.
Waltl, V., Oberegger coal-screen, 644.
Walton, James, election, M., 117.
Wakefield, traction-engines, 284.
Wardell, F. N., member of council, election, 490.
—, quoted, 508.
Ware, Buckinghamshire, boring, 14, 543.
Warwickshire, 11, 12, 17.
—, coal-field, 9, 13, 19, 20, 144, 154.
—, keuper formation, 562.
—, permian strata, 562.
—, south, absence of bunter, 562.
— and Lancashire coal-fields, depth to productive coal-measures between.—Discussion, 21, 561.
Washed coal, analyses, 58.
— —, analyses of coke, 61.
Wassel grove, 22.
— — sinking, 16.
Water-brake for lowering gob material, 634.
Water-cartridges, 4, 6, 168.
Water-circulating apparatus, 582.
Water-power, India, 353.
Water-spray system of laying coal-dust, 134, 135, 136.
Water-supply, Matabeleland, 29.
Water-tube boilers, 324, 332.
Waterloo and City railway, 475.
Waterworks, Gosford, 25.
Watson, John, election, N.E., 518.
Watson, S., *fencing-gates for winding-shafts*, 157.
Watts, William, election, N.E., 216.
Watts, W. W., quoted, 15.
Watkin, Sir E. W., 540.
Wauchope, John A., election, S., 88.
Waymel, —, quoted, 213.
Wealden, Dover, 544.
Weaver river, 555.
Wearmouth colliery, haulage, 221.
— —, cost of ropes, 255.
Webb, —, London and North Western railway, 561.
Webster, John, election, N.E., 518.
Wedgewood, Levison, election, N.S., 103.
Weeley, bore-hole, 18.
Wegener and other systems of firing steam-boilers with powdered coal, 321.—Discussion, 332.
— system of powdered coal-firing, 322, 324, 325, 326, 328, 335, 336.
Weinberg, E. A., refractory gold-ores of Queensland: their sources and treatment, 631.
Weirs, needle, 599.
Weithofer, K. A., geology of the Bayer shaft and adjacent portion of the Pilsen coal-basin, Bohemia, 590.
Welding, electric, 40.—Discussion, 52, 230.
—, —, Electric Welding Company, 472.
—, —, Jessop & Sons, 76.
Wells, Lionel B., prize for paper, 1.
Wells, nature and sources of suffocative gas met with in, together with further observations on the black-damp of coal-mines, 265.—Discussion, 273.
Wellsgreen colliery, pumping-engine tests, 100, 101.
Welsh coal, analysis, 544.
— —, compared with South African coal, 401.
Wemmer gold-mine, South Africa, 394, 412, 414, 415, 416, 417, 436, 438, 440, 441, 443, 449, 451.
West Flintshire, coal-field, 144.
— highlands, Ireland, 147.
— Kirby, 554.
— Lancashire and North Wales, explosions of fire-damp or coal-dust, 528, 651, 652.
— rand, South Africa, 427.
— — gold-mines, South Africa, 429.
— riding collieries, temperature, 231.
— Scotland, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
— —, explosions of fire-damp or coal-dust, 528, 651, 652.
— Yorkshire, coal-seams, 162, 163.
Western Australia, branch, N.E., 515, 516.
— —, gold-mining, 628.
— rand, South Africa, 410, 417.
Westphalia, experiments with powdered coal, 328.
—, Roth method of firing shots, 162.
Westfalit, 3, 4.
Wettdrift, South Africa, 396.
Wetter-dynamit, 3, 4, 5.
— —, composition, 167.
Wexford, blue marls, 153.
Wheeler-pans, India, Mysore gold-mines, 359.
Wheler, A. S., election, S.S., 572.
Whitacre junction, 19.
Whitaker, W., quoted, 14, 15.
White, George, election, M., 159.

White, William, quoted, 251.
Whitecross, boring, 25.
Whitehaven, coal-dust, 178.
—, coal-field, 554.
Whitelaw, Thomas, quoted, 255.
Williams, R. S., quoted, 497.
Wigan, Ald. Layland, mayor of, 517.
Wilje river, South Africa, coal-deposits, 400, 401.
Willans and Robinson, engine, 81.
Williams, Richard, election, N.E., 216.
Williams, Robert, election, N.E., 216.
Williams, Samuel Herbert, election, N.E., 518.
Williamson, Robert S., underground haulage at Cannock and Rugeley collieries, 564.
Wilson, J. R. Robinson, member of council, election, M., 490.
Wilts, north, coal-trough, 542.
Winding-engines, Birley collieries, 82, 83, 84.
— —, compound, 207.—Discussion, 212.
— —, expansion in, 604.
— —, improvements, 253, 254.
— —, La Grange pit, 213.
— —, Moss hall collieries, 557.
— —, Nunnery collieries, 79.
— —, Park collieries, 556.
— —, Woodworth progressive, cut-off gear for, 111.—Discussion, 112.
Winding-ropes, wire, 255.
Winding-shafts, fencing gates for.—Discussion, 156.
— —, upcast, methods of closing the tops.—Discussion, 122.
Winding and other engines, lead and lap of, 64.—Discussion, 68, 233.
Wingate grange colliery, wire-rope, 255.
Winkhaus, Bergassessor, blasting efficiency of explosives.—Discussion, 62.
—, quoted, 4, 167, 219.
Wire-ropes for winding, 255.
Wirral, Cheshire, 554.
— colliery, Neston, Cheshire, coal-washing plant, 55.—Discussion, 59.
Witfontein, South Africa, 427.
Witteberg, South Africa, 398.
Witwatersrand, description of the gold-ores, 433.
—, geological description of the gold-mines, 378.
—, gold metallurgy, 625.
— district, present method of declaring the monthly output of gold with a suggestion for its alteration, 624.
— gold-bearing series, South Africa, 402.
— gold-mine, South Africa, 389, 418, 444.
— reef, South Africa, 388.
Wolhuter gold-mine, South Africa, 412, 438, 449.
Wonderfontein river, South Africa, 396.
Wood, Arthur Nicholas Lindsay, election, N.E., 518.
Wood, W. O., quoted, 60.
Wood and Burnett, coal-tipplers, 171, 172.
— — —, screening plant, 80.
Wood, Matabeleland, 30.
Woodcock, A. B., quoted, 254.
Woodhouse, J. T., 339.
—, quoted, 153.
Woodhouse junction station, 81.
Woodward, H. P., chairman, election, W.A.B., N.E., 516.
Woodworth, B., automatic cut-off gear, 70.
—, *cut-off gear for winding-engines*, 115, 116.
—, *lead and lap of winding and other engines*, 73.
—, *modern coal-tipplers*, 172.
—, progressive cut-off gear for winding-engines, 111.—Discussion, 112.
Wool-manufacturers, comparative mortality, 243, 244.
Worcester gold-mine, South Africa, 412, 443, 449.
Worcestershire, 11.
—, coal-field, 15, 16, 17, 19.
Working of mines, notes of papers from the transactions of colonial societies, etc,, 573.
— — traction-engines, 285.
Workmen, India, gold-mines, 362.
—, Matabeleland, 30.
Wormald, H., adjustable piston-rings, 118.—Discussion, 120.
Wyken, Warwickshire, 13.
—, —, coal-seams, 154.
Wynaad, India, gold-mining, 346, 349, 350, 351, 352, 353, 354.
Wyper, James, member of council, election, S., 88.
Wyre forest, coal-field, 22, 23, 24, 25.

Yerrakonda gold-mines, India, Mysore, statistics, 366, 367.
Yoch, —, quoted, 196.
—, coal-cutting machine, 186, 192, 193.
Yoredale grits, 27.
— rocks, 22.
— —, Endon, 562.
Yorkshire, coal, analysis, 544.
— coal-field, 19, 20, 341.
—, coal-seams, 162, 163.
—, deaths from explosions of fire-damp and ignitions of gunpowder, 530.
—, explosions of fire-damp or coal-dust, 528, 651, 652.
—, lias, 148.
—, Micklefield colliery, explosion, 502, 503, 508, 509, 511, 526, 527.
—, oolite, 148.
—, road engines, 295.
—, south, coal-field, 19.
—, Thornhill collieries, coke, 61.
—, west riding, comparative mortality, 243, 244.
—, — —, traction-engines, 284.

Yorkshire, west riding collieries, temperature, 231.
— and Nottinghamshire coal-field: geological suggestions relative to its eastward extension beneath the permian and secondary strata into Lincolnshire, 143.—Discussion, 150.

Zambesi river, Matabeleland, 29.
Zechstein fossils, Stockport, 562.
— measures, 27.
— permian, 342.
— —, South Lancashire, 26, 27.
Zeiller, R., quoted, 400, 541, 548.
Zerener, Dr., system of electric-welding, 40, 50.
Zimbawe, Matabeleland, 36.
Zinc, South Africa, 397.
— blende, roasting, 375.
— works, Collinsville, Illinois, U.S.A., 375.
Zoutpansberg, Transvaal, 378, 399.
Zuikerbosch river, South Africa, 382.
Zululand, South Africa, 378, 399.
Zuurberg, South Africa, 398.
Zwarteberg, South Africa, 398.
— mountains, carboniferous fossils, 397.
— series, South Africa, 399.



BRANNER EARTH SCIENCES LI
622.06
I59
v 11
1895-9